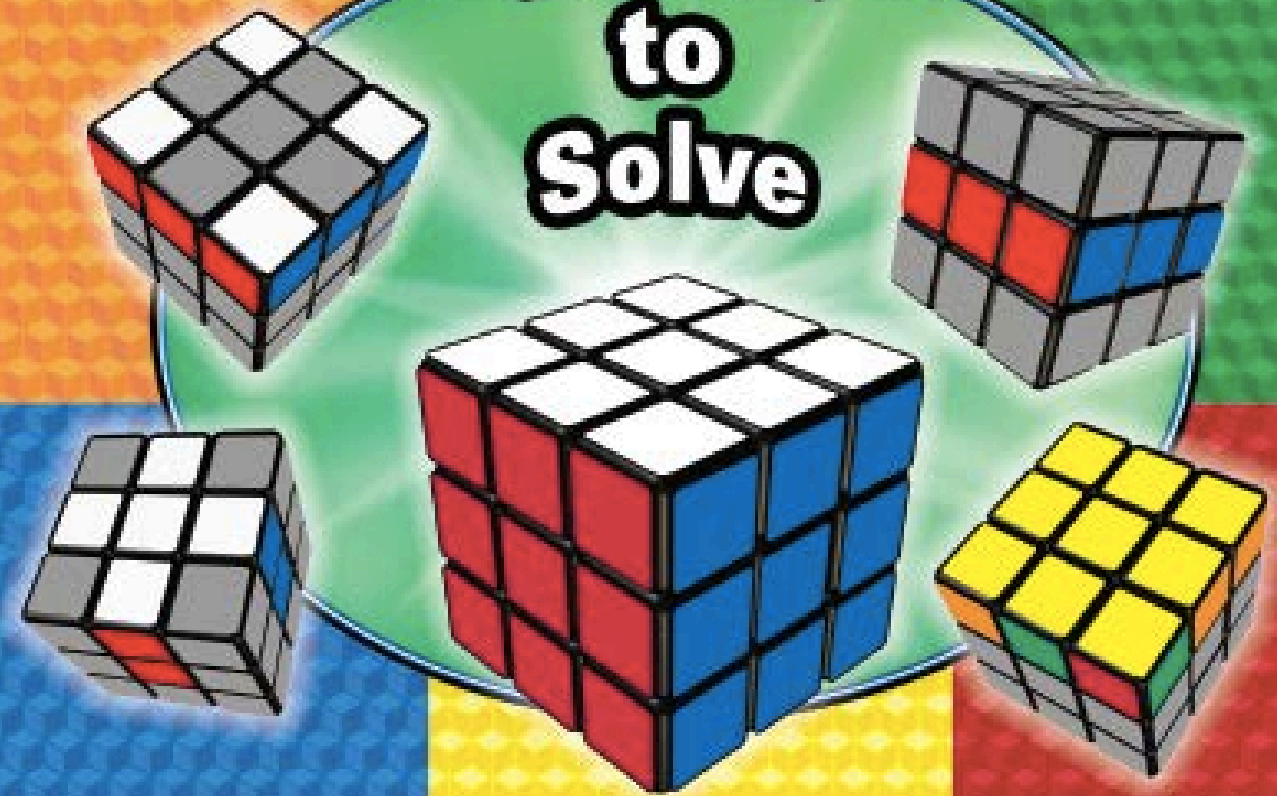
STEM ACCREDITED

LEARN TO SOLVE THE RUBIK'S® CUBE

Updated Stages 2 & 3

You CAN do the Rubik's Cube

Learn to Solve



Lessons include:

- Meet the Cube
- The WHITE Cross
- The WHITE Corners
- The MIDDLE Layer
- The YELLOW Face
- Positioning the YELLOW Corners & Edges

Learn to Solve

A Curriculum for Teaching How to Solve

The

Rubik's® Cube

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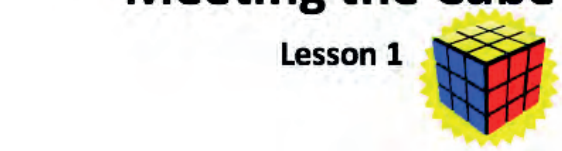
21st Century Learning Skills		
Learning & Innovation Skills: • Creativity and Innovation • Critical Thinking and Problem Solving • Communication and Collaboration	**Life & Career Skills:** • Flexibility and Adaptability • Initiative and Self Direction • Social and Cross-Cultural Skills • Productivity and Accountability • Leadership and Responsibility	**Media Literacy:** • Information Literacy

Meeting the Cube

Lesson 1

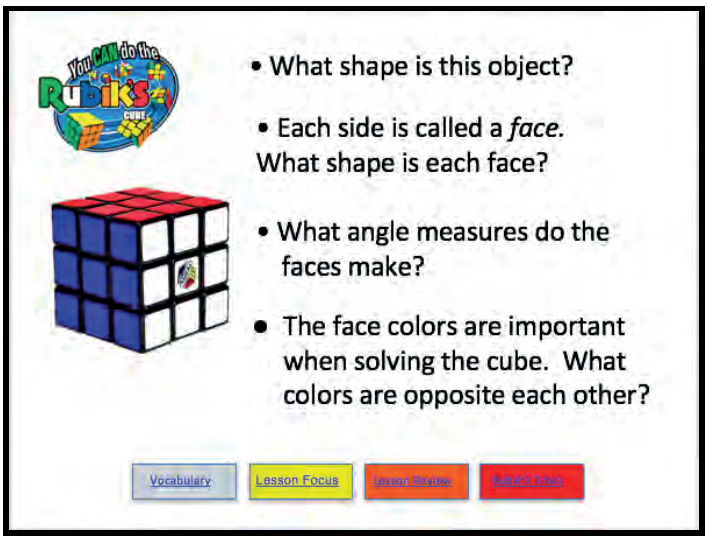


CONTENT STANDARDS & SKILLS: LESSON 1

Grade	Common Core	National Council of Teachers of Mathematics
K - 2	K.CC.5 - Answer "How Many Questions. K.MD.1 - Measurable attributes of objects K.G.1 - Describe the relative positions of these objects using terms such as *above*, *below*, *beside*, *in front of*, *behind*, and *next to*. K.G.3 - Identify shapes as two-dimensional K.G.4 - Compare two- and three-dimensional shapes 1.G.1 -Defining attributes of shapes 2.G.2 -Partition a rectangle into rows and columns of same size squares	**Number and Operations** • recognize "how many" in sets of objects **Algebra** • sort, classify, and order objects by properties **Geometry** • recognize, name, build, draw, compare, and sort two- and three- dimensional shapes, • describe attributes and parts of two- and three- dimensional shapes, • recognize shapes from different perspectives
3 - 5	3.MD.1 - Telling time 4.G.1 -Identify angles, perpendicular and parallel lines in two-dimensional figures 5.NF.4b - Area of a rectangle using unit squares 5 .MD.3 - Volume of a cube 5.G.3 - Attributes of two-dimensional figures	**Geometry** • identify attributes of two- and three-dimensional objects; develop vocabulary to describe the attributes. • understand relationships among angles, side lengths, perimeters,area, and volume. • describe objects and patterns **Measurement** • understand attributes such as length, area, weight, and volume
6 - 8	6.G.2 - Volume of a right rectangular prism	**Geometry** • precisely describe two- and three-dimensional objects using their attributes. • use two- dimensional representations of three- dimensional objects to solve volume and surface problems **Measurement** • select appropriate units to measure perimeter, area, surface area, and volume

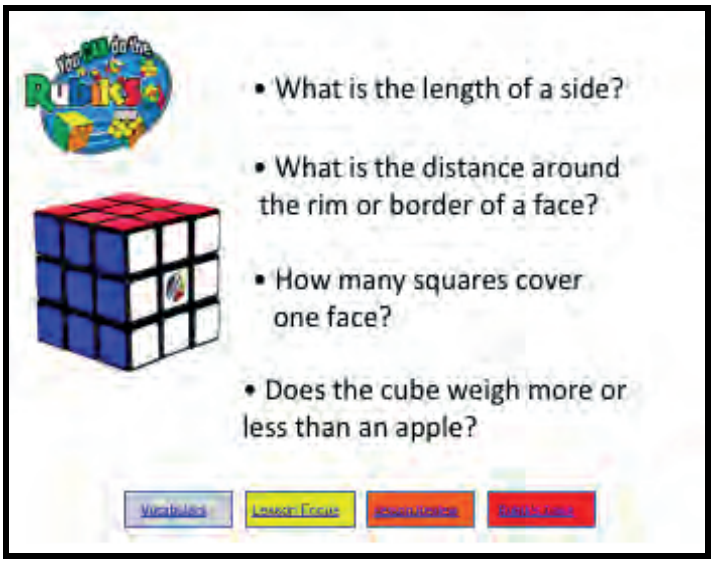
Lesson Content:

The questions on these slides are meant to focus students on the characteristics of the Rubik's Cube. Depending on the grade level of your students, these questions may or may not be appropriate. Many of the slides are animated so what you see in this guide may not appear all at once in the presentation.



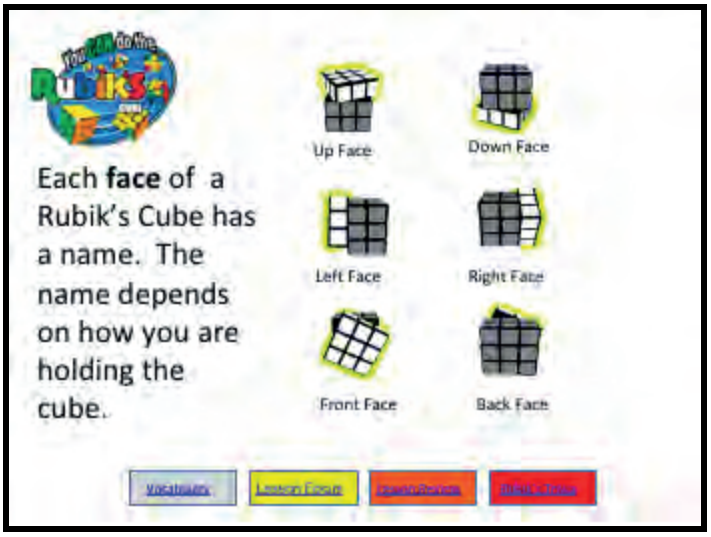
Slides 3 - 4

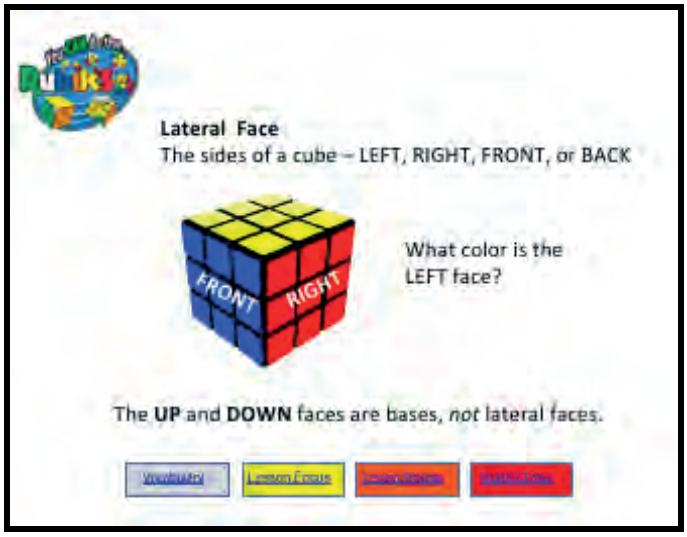
- Cube. Compare squares and cubes.
- The term **face** will be used throughout the *You CAN Do the Rubik's Cube* materials so you will want to make sure your students understand this term.
- 90^0 Turns of faces will be described as **¼ turn**, **¼ rotation**, or **90^0 turn**. You may want to explain this terminology with your students before you begin.
- WHITE is opposite YELLOW.
  BLUE is opposite GREEN.
  RED is opposite ORANGE.



- 3 nonstandard units (sides of the tiles) Perhaps you want students to practice with standard measurement.
- 12 units. Perimeter contains the words "rim" and "meter". Have you used these cues to help students remember the meaning of perimeter?
- 9 sq units
- Answers may vary.

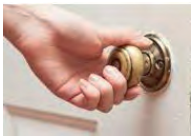
Slides 5 - 6





Turning the UP and DOWN faces is like opening and closing a jar or screwing in a lightbulb. This imagery helps students orient the cube.

Grab hold of the handle of a mug to turn the LEFT and RIGHT faces. Taking a sip turns the cup toward you. Dump the cup out by turning it away from you.



The FRONT and BACK moves could be imagined as turning a doorknob or combination lock.

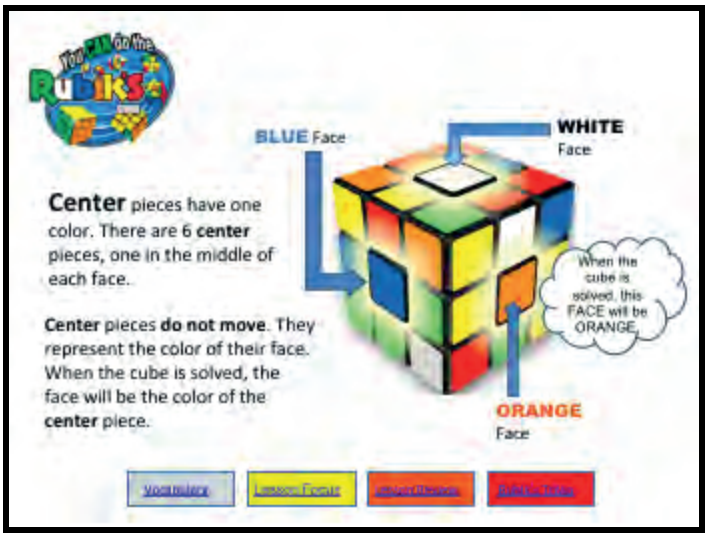
You will see reference to these images other slides.

HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.

HINT: Keeping the cube on the table or desk may help students attend to the orientation of the cube which is an important concept as they solve. It is easier to identify the UP face when the cube is on a flat surface than when it is in moving hands.

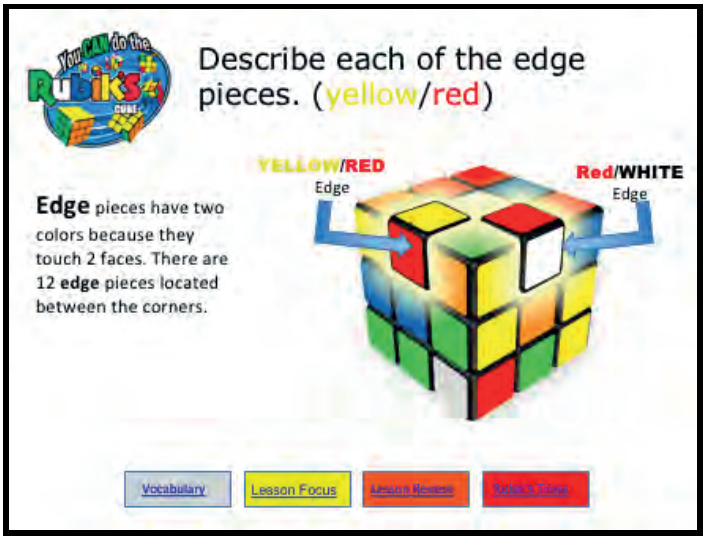
You may want to skip the Lateral Face slide with students younger than 5th grade. However, at all grade levels, it is important to stress that the FRONT face is the one facing you. It can be any color.

Slides 7 - 9



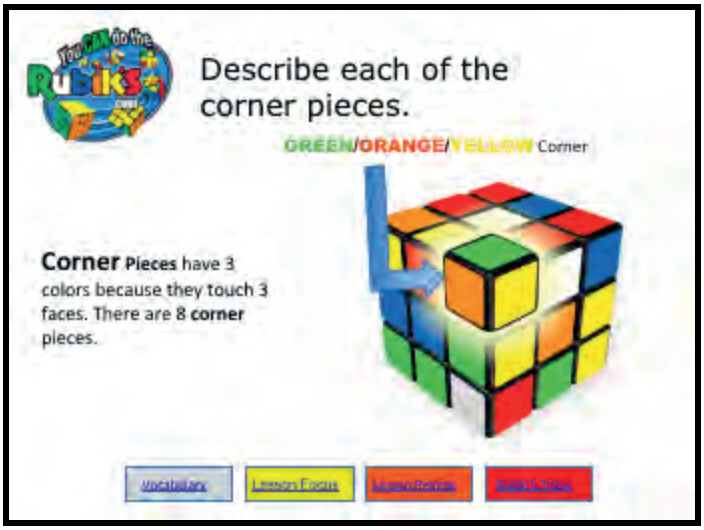
The important information on this page is that the CENTER tile tells you what color the face will be when the cube is solved.

Have students identify a specific color face. Ask them to identify the color of the opposite face. Students begin to realize that BLUE is always opposite GREEN; RED and ORANGE are always opposite; and WHITE and YELLOW are always opposite.



Stress that EDGE pieces have 2 colors. Ask students what color combinations could **not** be edge pieces. (There will be no BLUE/GREEN edge pieces because BLUE and GREEN are opposite faces, for example.)

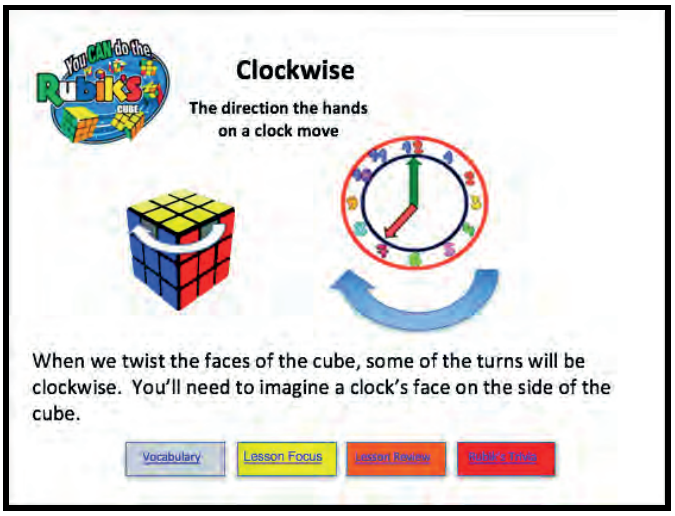
Have students "pinch" the EDGE pieces between 2 fingers to emphasize the 2 tiles.

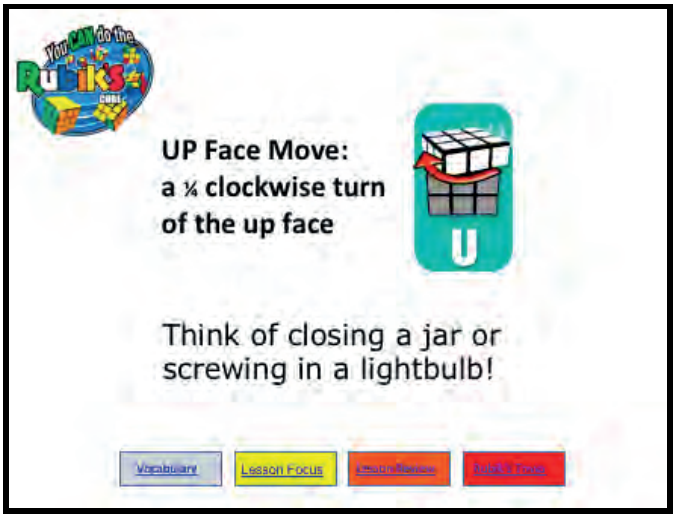


Once students start solving, they tend to confuse EDGES and CORNERS. Have students hold the CORNERS with 3 fingers.

You may want to introduce the term vertex with older students. This may help them differentiate the CORNERS from the EDGES. With younger students, have them identify the point that CORNERS have. EDGES do not have points.

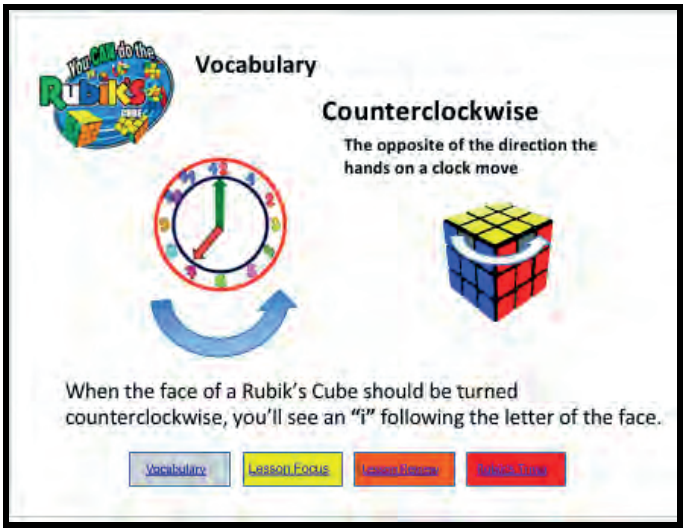
Slides 10 - 11





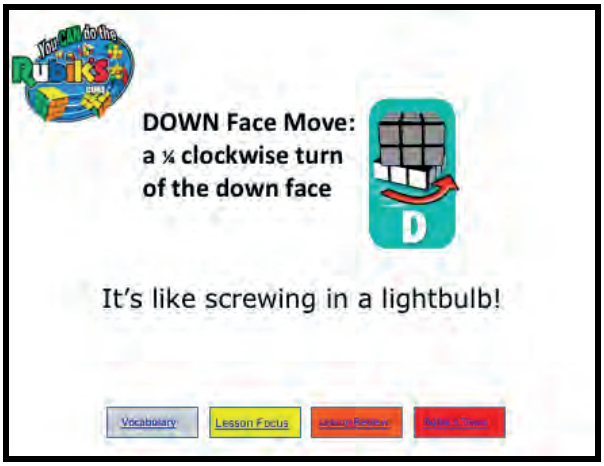
The clockwise turn is as if you are looking at the face. You may want to put small clock faces on the sides of the cube for younger students. With older students, you may want to use mental imagery of the clock face on the cube face.
HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.

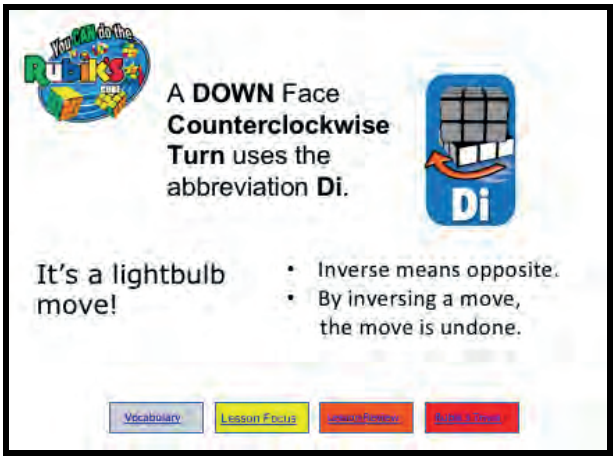
Slides 12 - 13

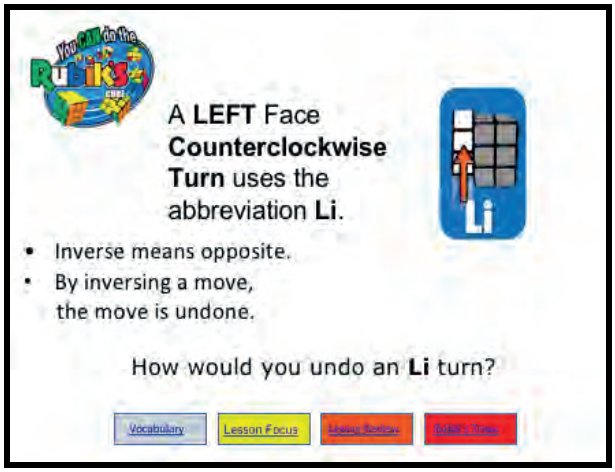


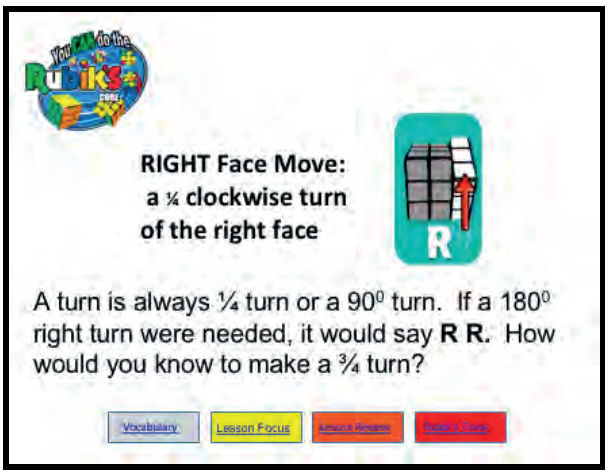
A counterclockwise or inverse turn is always indicated by a lowercase i after the face name. There is a slide demonstrating each turn and its inverse.

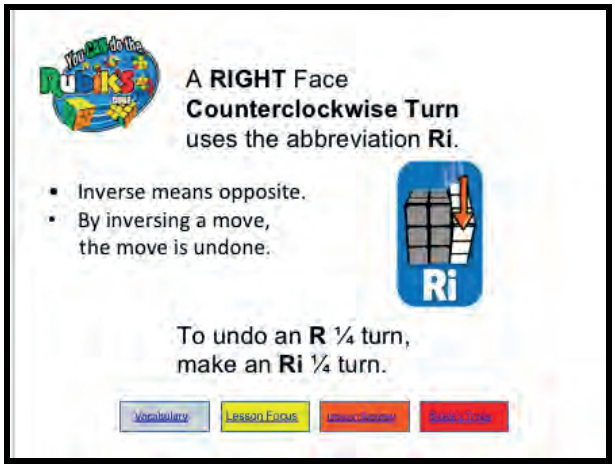
Slides 14 - 19 Have students turn their cubes as you go through the slides.
HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.



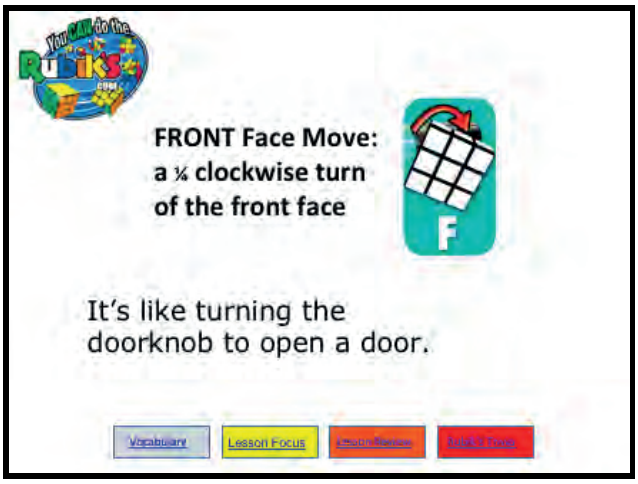


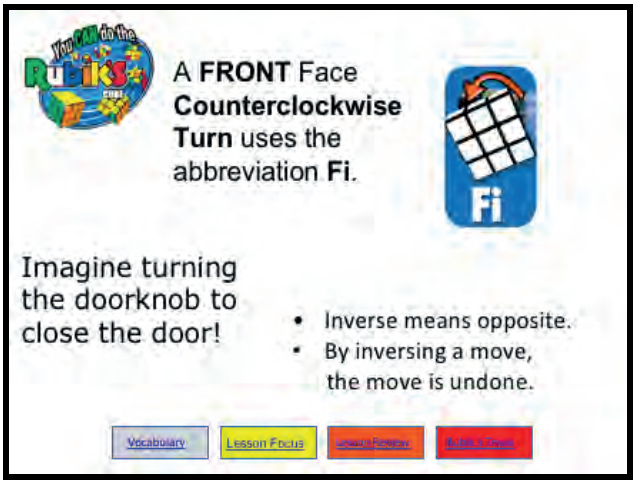


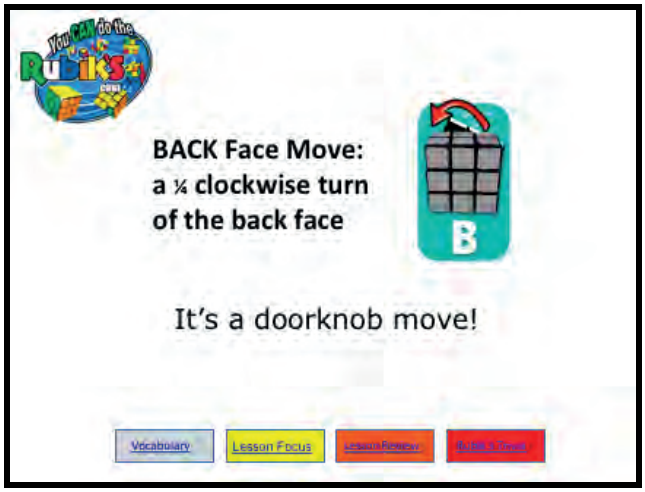


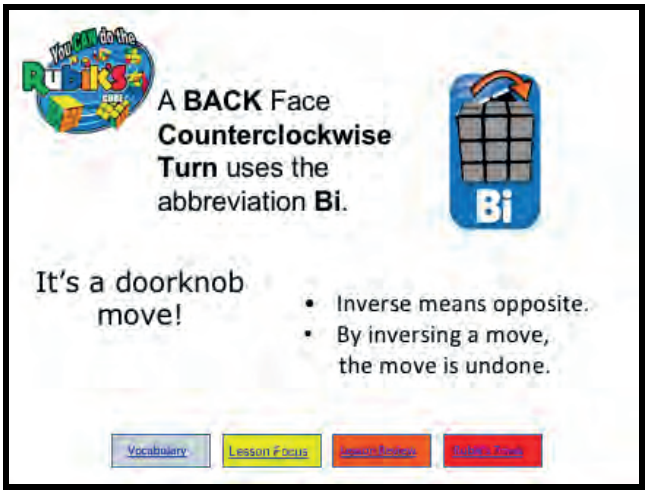


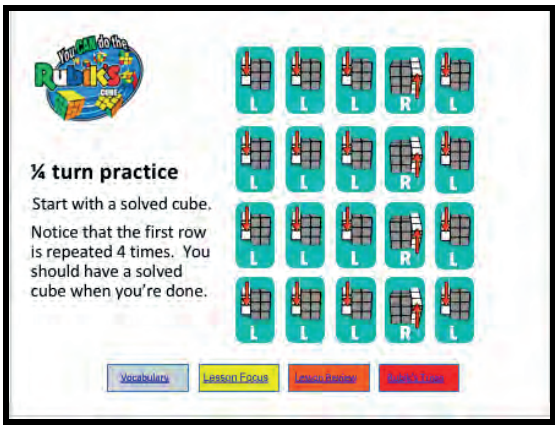
Slides 20 - 23 Have students turn their cubes as you go through the slides.
HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.







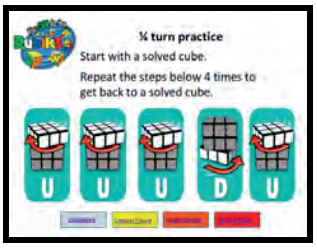




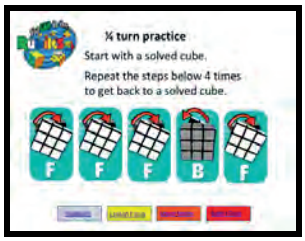
Slides 24 -29 The next series of slides provides practice in making the turns. Some of the slides say you should start with a solved cube. This is not really important although it will make it easier for you (and perhaps your students) to quickly see if everyone has made the correct turns.

If 4 of the same turn or turn sequence have been made, that part of the cube will remain unchanged. At the end of this sequence, the cubes should be back in the starting position.

Hint: Using the military cadence (♫"LEFT, LEFT, LEFT, RIGHT,LEFT"♫) or some other song or rap may be help students learn the turns. See pages 14 and 15 for additional practice suggestions.

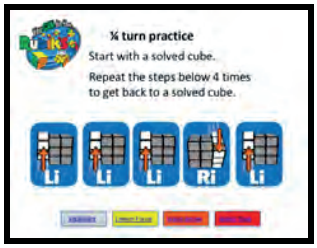


At the end of this sequence, the DOWN face will be turned once clockwise from the starting position. The UP face will revert back to its original state.



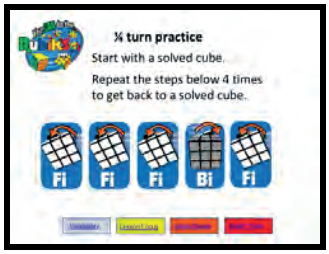
At the end of this sequence, the BACK face will be turned once clockwise from the starting position. The FRONT face will revert back to its original state.

At the end of this sequence, the RIGHT face will be turned once counterclockwise from the starting position. The LEFT face will revert back to its original state.



At the end of this sequence, the DOWN face will be turned once counterclockwise from the starting position. The UP face will revert back to its original state.

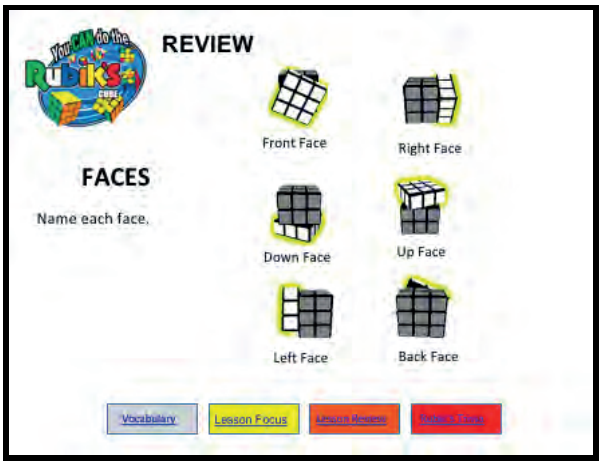
At the end of this sequence, the BACK face will be turned once counterclockwise from the starting position. The FRONT face will revert back to its original state.



Do as many of these turn practices as needed. The goal is to realize that clockwise and counterclockwise will turn differently depending on the face. Remember, the clock is on the face you are turning!

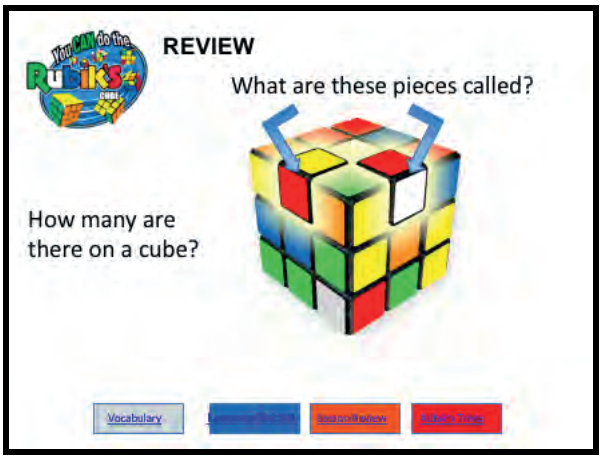
Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Please modify your presentation as best meets the needs of your students.

REVIEW: Slides 30 - 34



The names of the faces appear on click. The order is random.

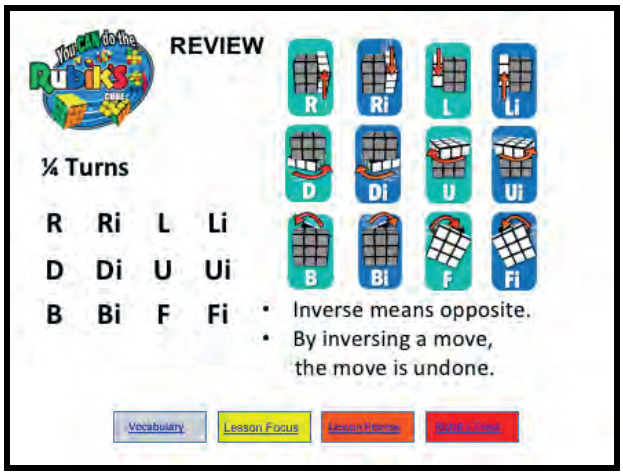
Remember, BLUE is opposite GREEN.
ORANGE is opposite RED.
WHITE is opposite YELLOW.



Remember, EDGE pieces have 2 colored tiles.

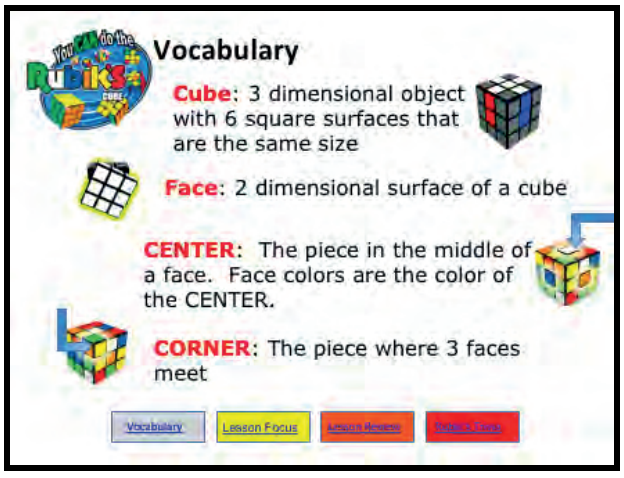
There are 12 edge pieces on a Rubik's Cube.

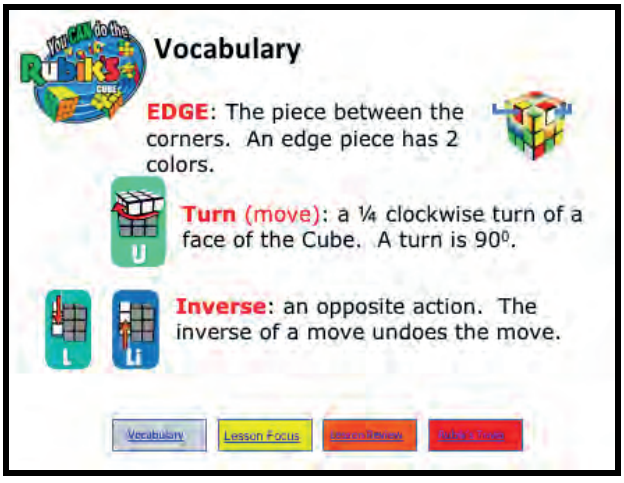
Remember, CORNER pieces have a point or vertex. They have 3 tiles. (3 colors)



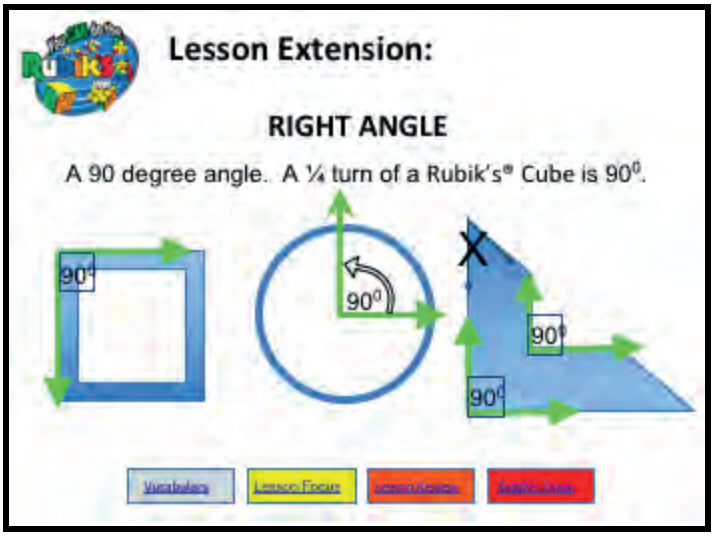
Turns are always ¼ rotations or 90^0. The opposite or inverse of a turn is always indicated by a lowercase **i** following the abbreviation for the name of the face. See pages 14 and 15 for additional ¼ rotation practice ideas.

Vocabulary: Slides 35 - 36





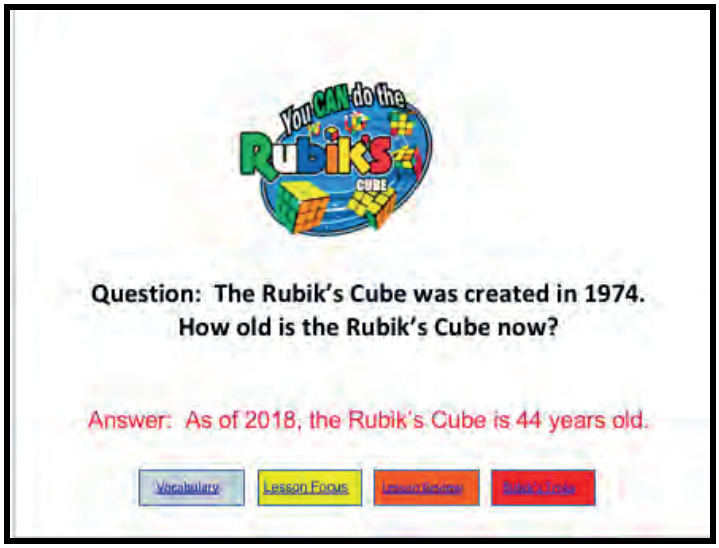
Math Connection: Slide 37



With younger students, a right angle is often described as a "square" corner. With a Rubik's Cube, you can begin to develop an understanding of angle as a measure of turning.

A connection to 90^0 angle as a ¼ turn is another way to view fractions as part of a whole. A whole turn is 360^0.

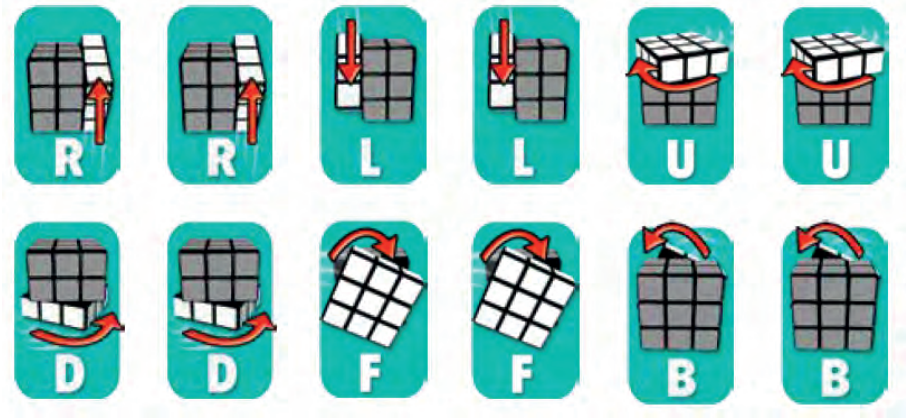
Trivia: Slide 38



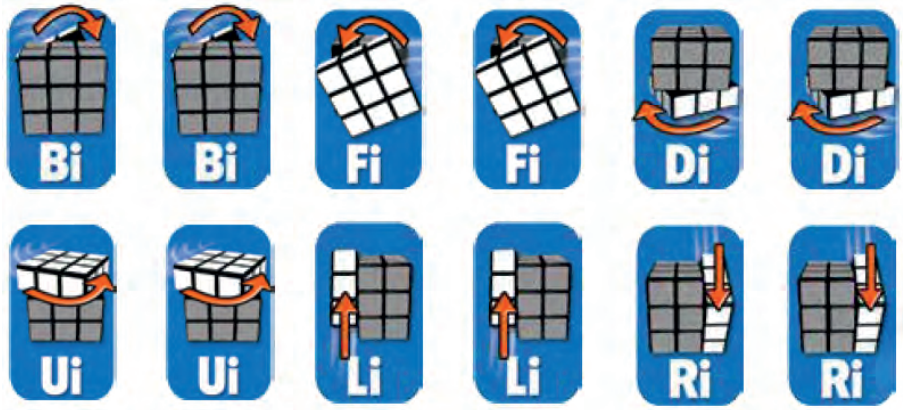
This could be the beginning of a class book, student journal, research project, or bulletin board.

¼ Turn Practice

Multicolored Cross (if you begin with a solved cube)



To return to a solved state

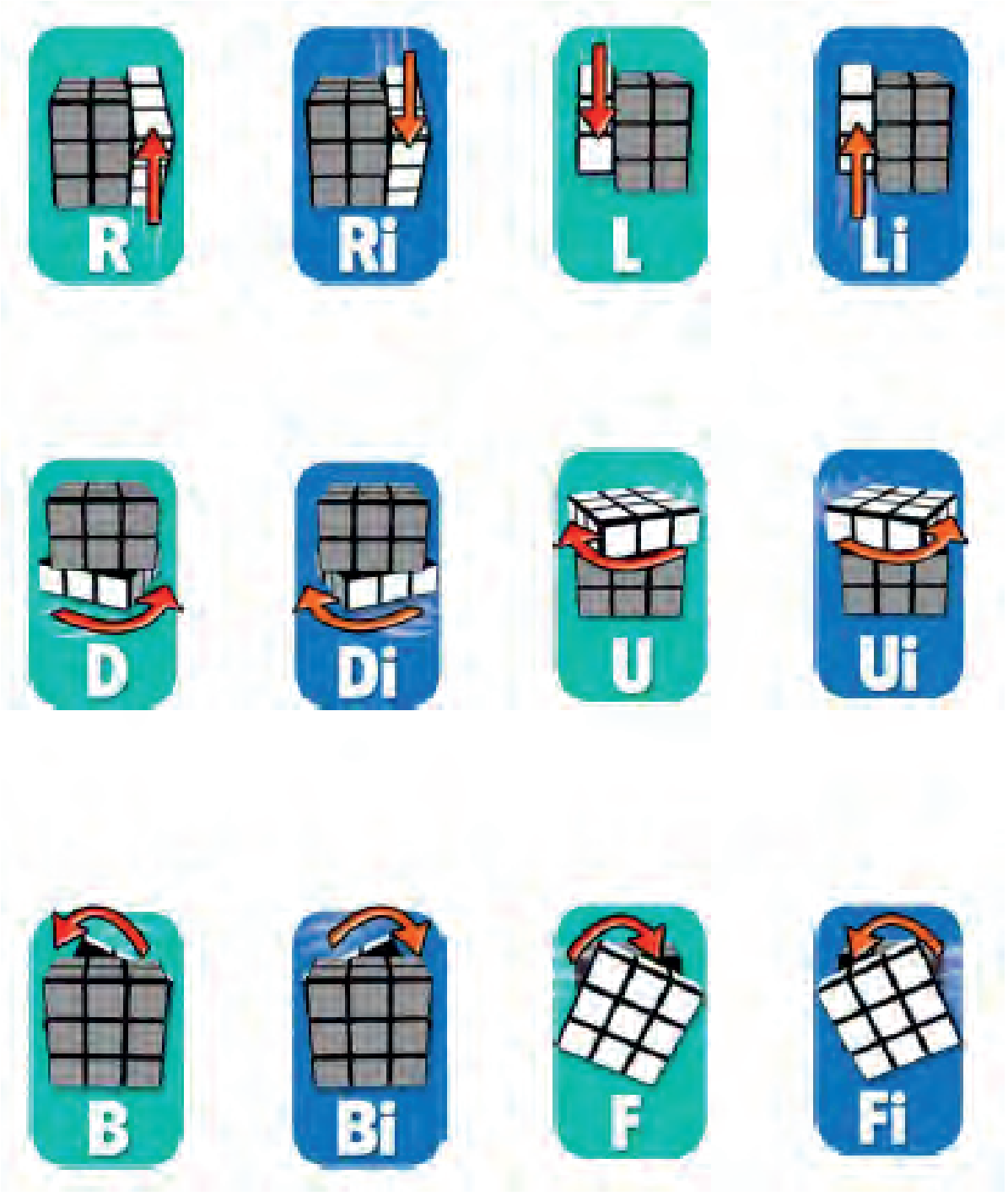


Square in the Middle (if you begin with a solved cube)

Return to a solved state

Create Your Own Practice Patterns

Cubes can be in any state to do this activity. Use the images on the next page to create cards. Students can create a series of ¼ turn sequences for one another. Have them create the "undo" sequence as well to return the cube to its original state. Have students record their sequences so that they become familiar with the notation for the turns.



¼ Turns

A ¼ turns is clockwise unless an “i” follows the letter. Then the turn is counter-clockwise.

SO…

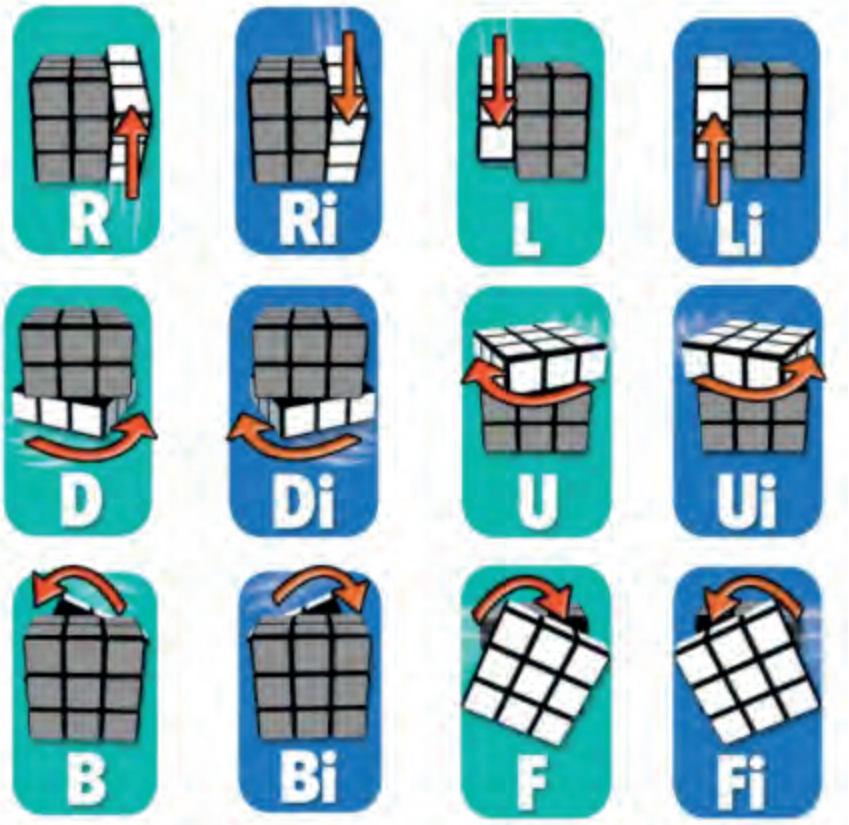
R is a clockwise turn of the RIGHT face.

Ri is a counterclockwise turn of the RIGHT face.

R Ri L Li

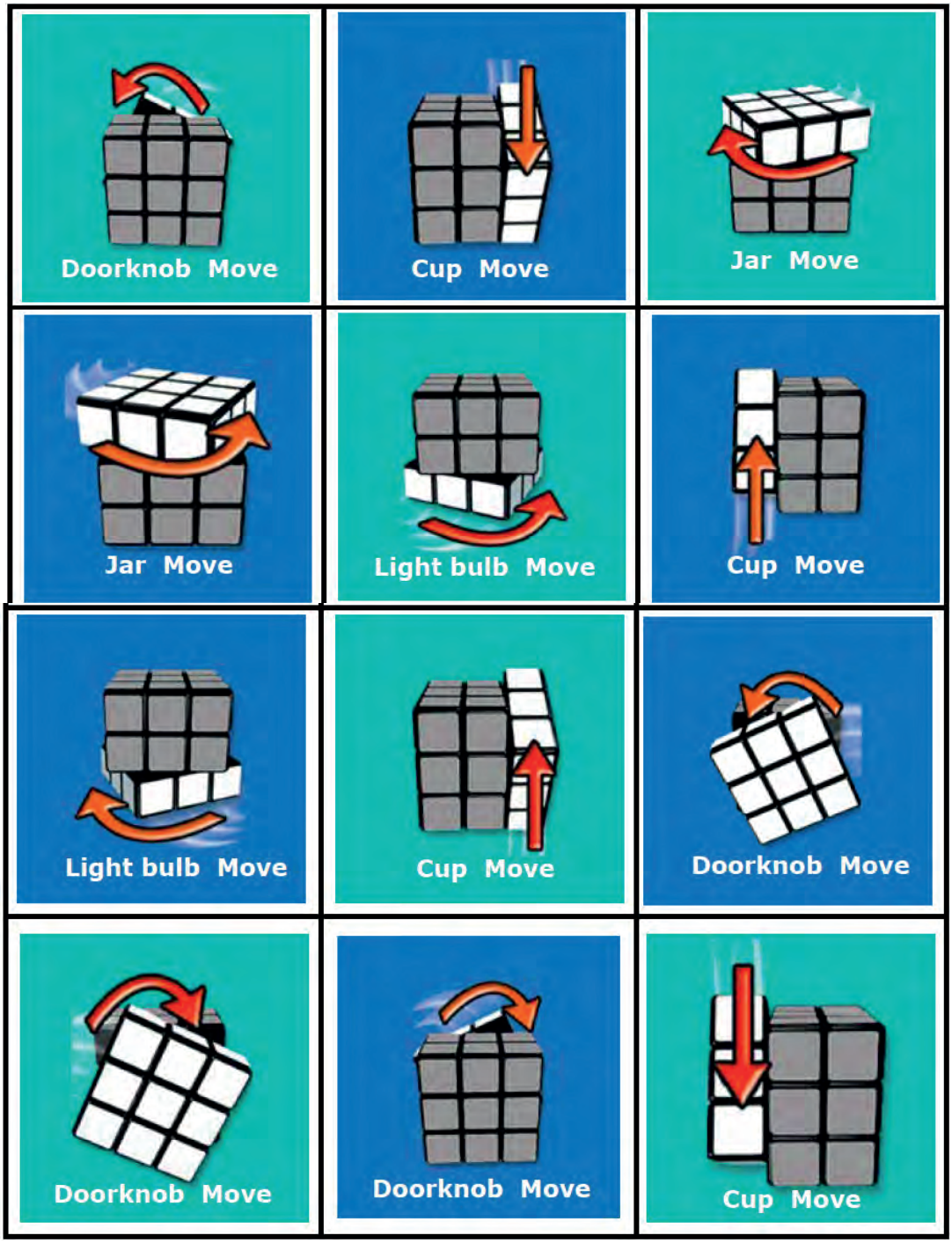
D Di U Ui

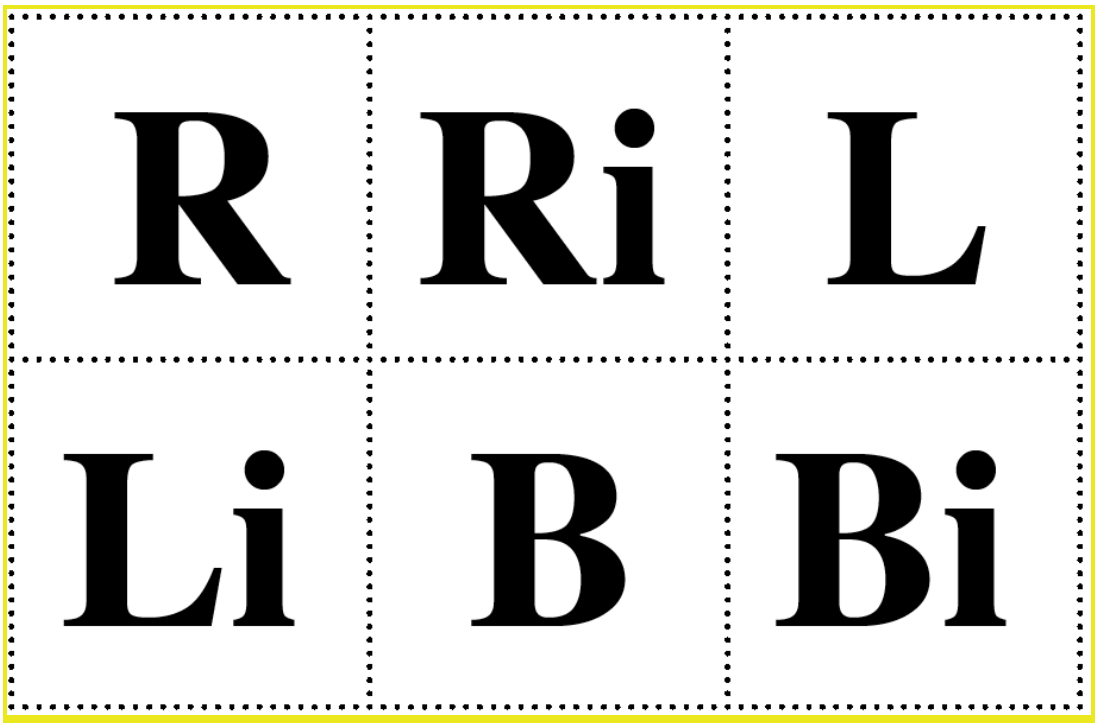
B Bi F Fi

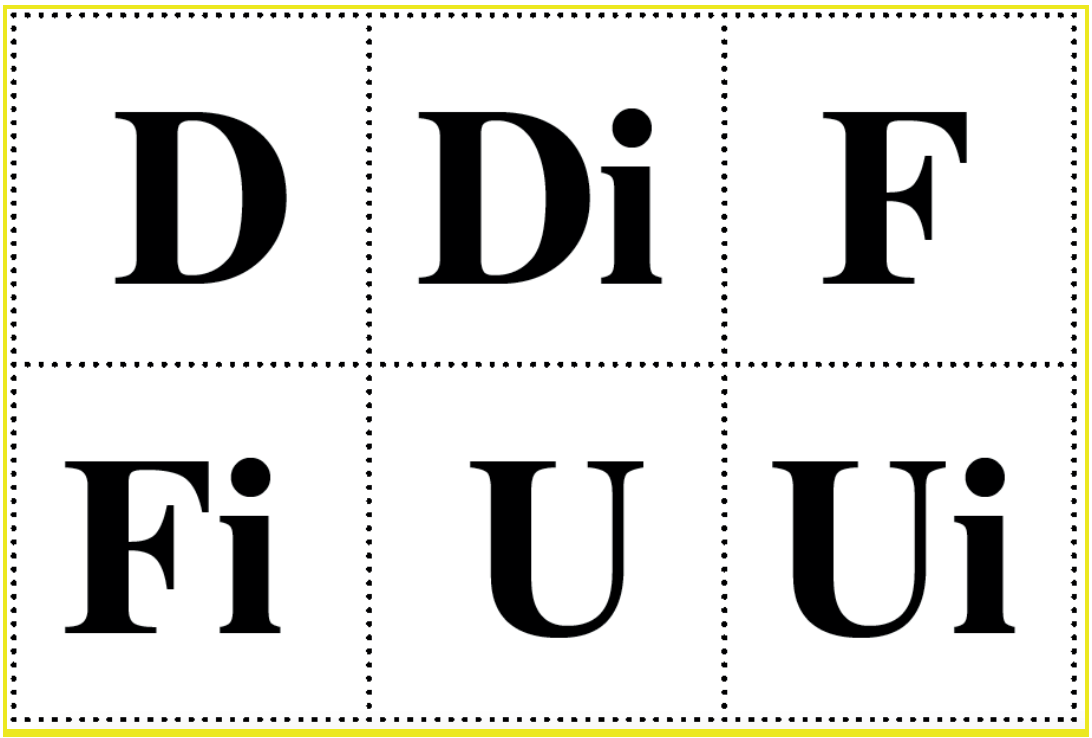


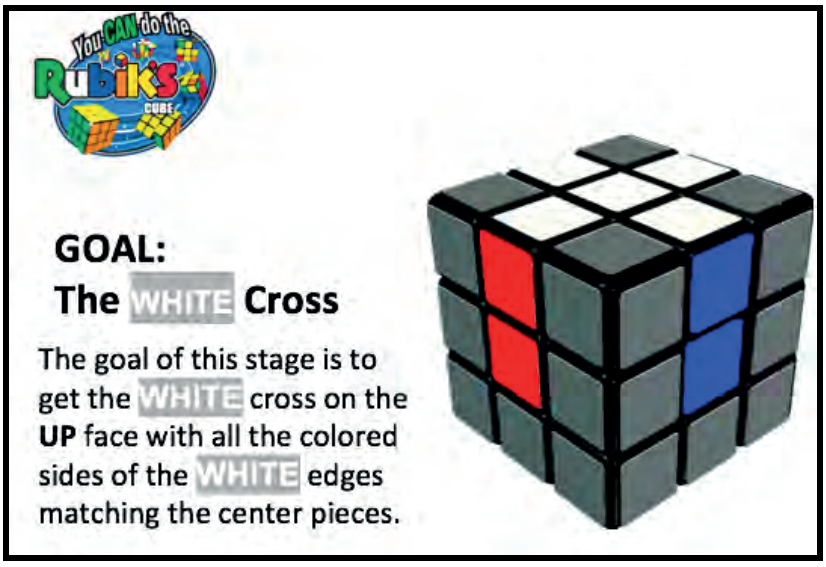
Memory Game

- Cut out each card.
- Place cards face down on the table.
- Take turns trying to match the image with the correct letter.









CONTENT STANDARDS & SKILLS: LESSON 2

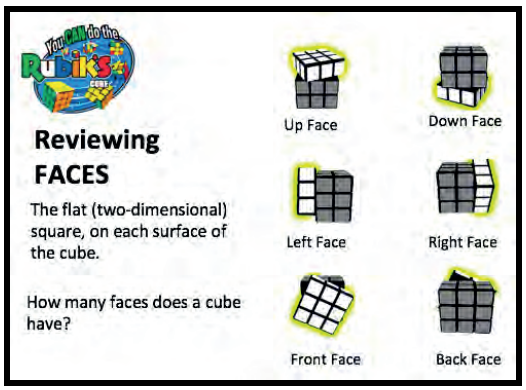
Grade	Common Core	NCTM
K-2	K.G.1 Names of shapes 1.G.1 Defining attributes of shapes 1.OA.B.3 Apply properties of operations as strategies	**Geometry** • describe attributes and parts of two- and three- dimensional shapes • create mental images of geometric shapes • recognize shapes from different perspectives • relate ideas in geometry • recognize geometric shapes in the environment
3-5	3.OA.B.5 Apply properties of operations as strategies 4.OA.C.5 Generate a number or shape pattern that follows a given rule. Identify apparent features of the pattern that were not explicit in the rule itself. 4.G.1 Identify angles, perpendicular and parallel lines in two-dimensional figures	**Number and Operations** **Geometry** • identify attributes of two- and three- dimensional objects; develop vocabulary to describe the attributes • describe objects and patterns • recognize geometric ideas and apply them in the classroom and everyday life
6-8	6.EE.A.3 Apply the properties of operations to generate equivalent expressions. 6.EE.A.4 Identify when two expressions are equivalent 7.EE.A.2 Understand that rewriting an expression in different forms in a problem context can shed light on the problem and how the quantities in it are related. 8.G.A.1 Verify experimentally the properties of rotations, reflections, and translations.	**Geometry** • precisely describe two- and three-dimensional objects using their attributes

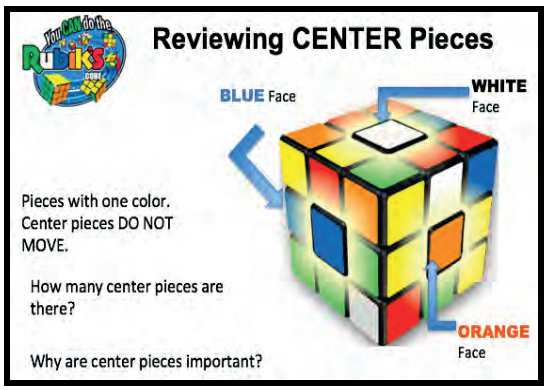
The questions on these slides are meant to focus students on the characteristics of the Rubik's Cube. Depending on the grade level of your students, these questions may or may not be appropriate. Many of the slides are animated so what you see in this guide may not appear all at once in the presentation.

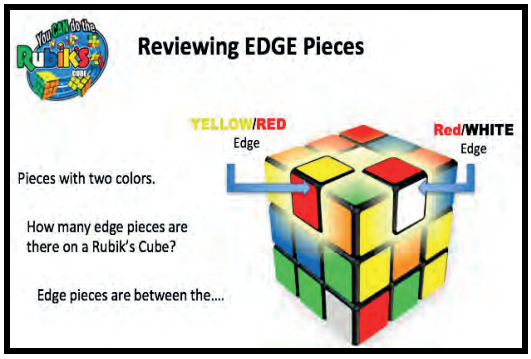
Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Please modify your presentation to best meet the needs of your students.

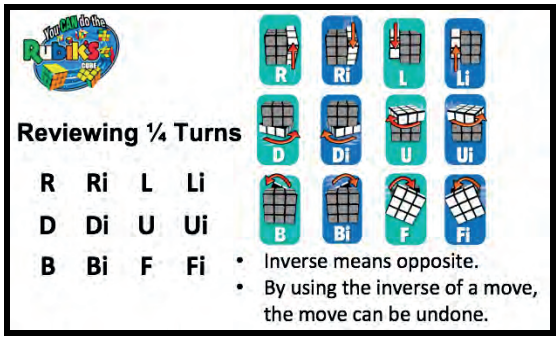
Review: Slides 3 - 7

As you review the parts of the cube, emphasize the orientation (i.e. the FRONT face faces you) and how this differs from the color of the faces which is determined by the CENTER tile. The EDGE pieces will be the focus of the WHITE Cross so make sure students can readily identify those pieces.





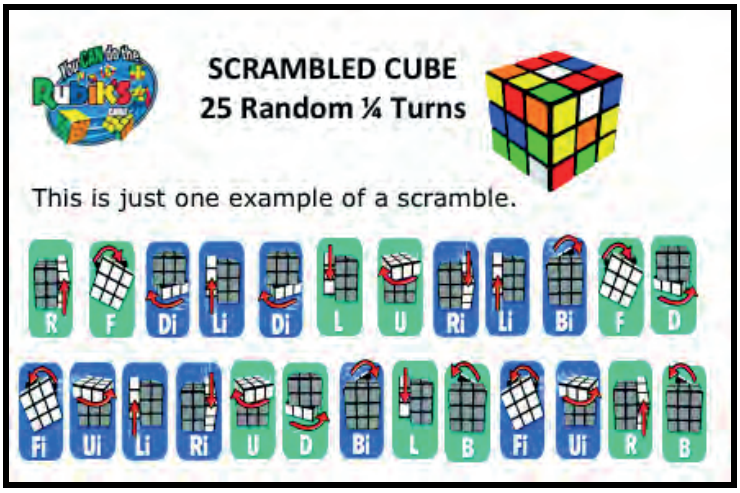




HINT: Have students place their flat palms on the face you want them to turn. This is a good strategy to use at any stage of solving the cube.

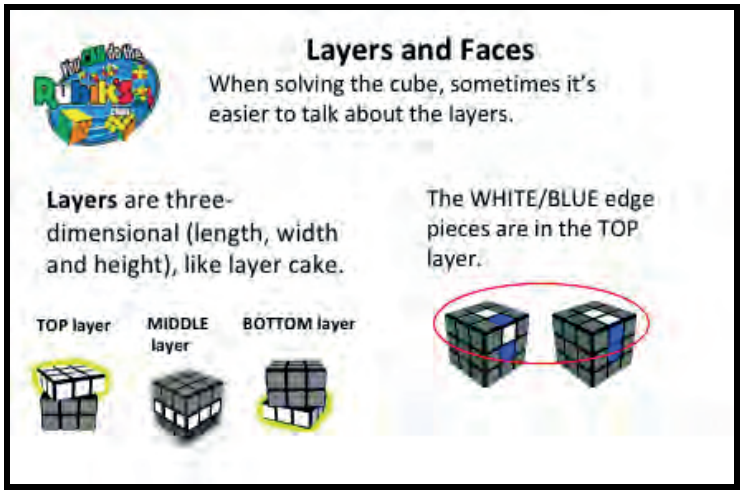
HINT: Keeping the cube on the table or desk may help students attend to the orientation of the cube which is an important concept as they solve.

Lesson Content: Slides 8 - 21



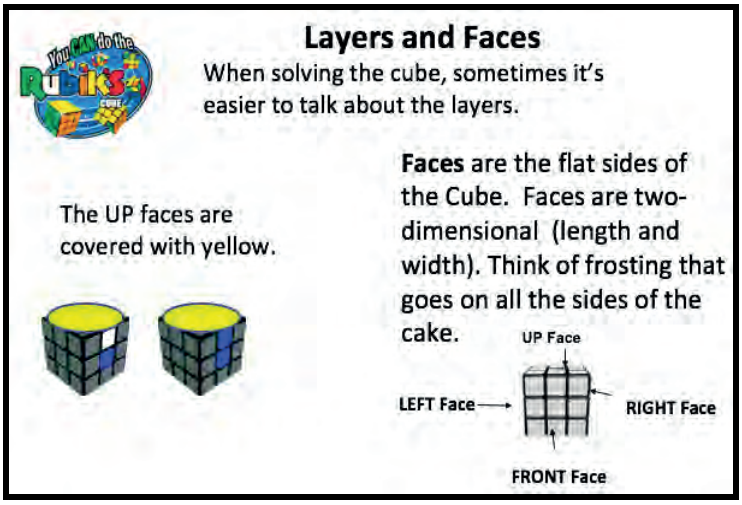
In order to solve a Rubik's Cube, it must first be scrambled. A **scramble** is 25 random ¼ turns.

Have the students look at the sequence. Notice that there are no adjacent moves that are opposites of one another. (Ri never follows R.) Have students explain why this is true.

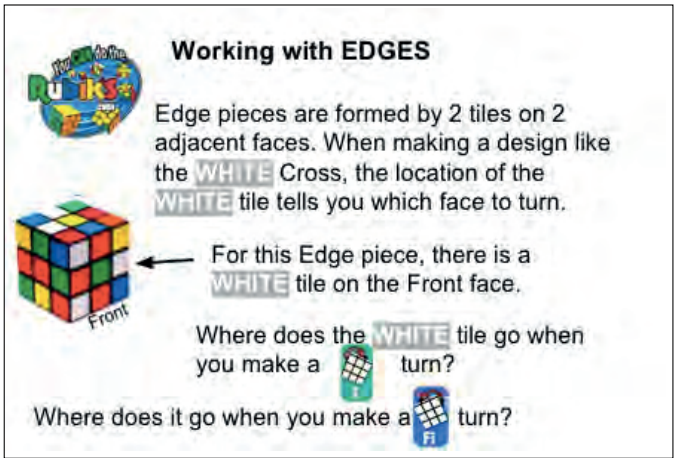


The difference between **layers** and **faces** can be confusing. The cake analogy may help. Layers of the cube are like layers of a cake. Faces on the cube are the frosting on the cake.

In this lesson, talking about the layers is an intermediary step to getting the WHITE tiles on the UP face. This will probably make more sense in the next series of slides.



Slides 11 - 13

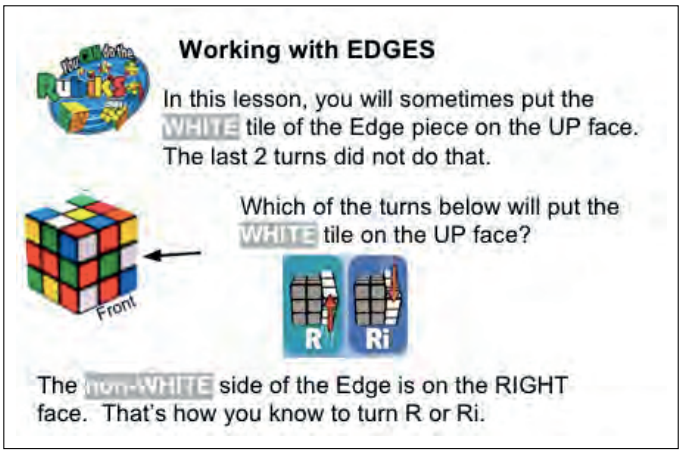


These slides are an opportunity to think purposefully about how the cube moves. The number of tiles on a piece determines the number of faces you can turn to move that piece. The focus here is on Edge pieces which are what you will need to make the WHITE Cross.

Where does the WHITE tile go when you make a F turn? The WHITE tile will go to the BOTTOM layer on the FRONT face.

When you make a Fi turn (on the original diagram), the WHITE tile will be on the TOP layer on the FRONT face.

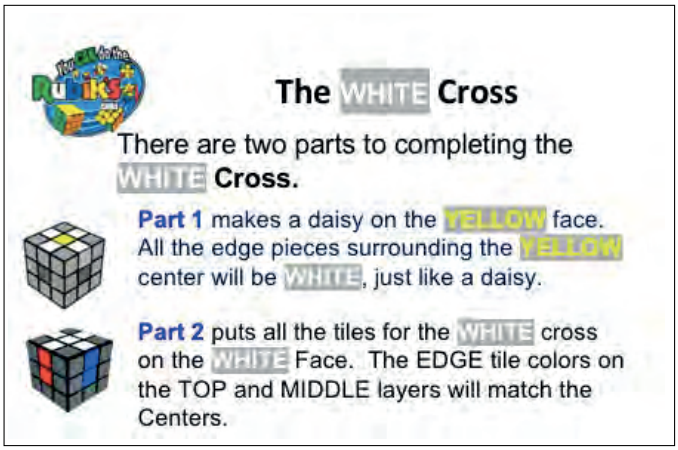
Fi was a better move than F because the WHITE tile is on the TOP layer, but neither turn puts the WHITE tile on the UP face.



Making an R turn will put the WHITE tile on the UP face, next to the YELLOW Center.

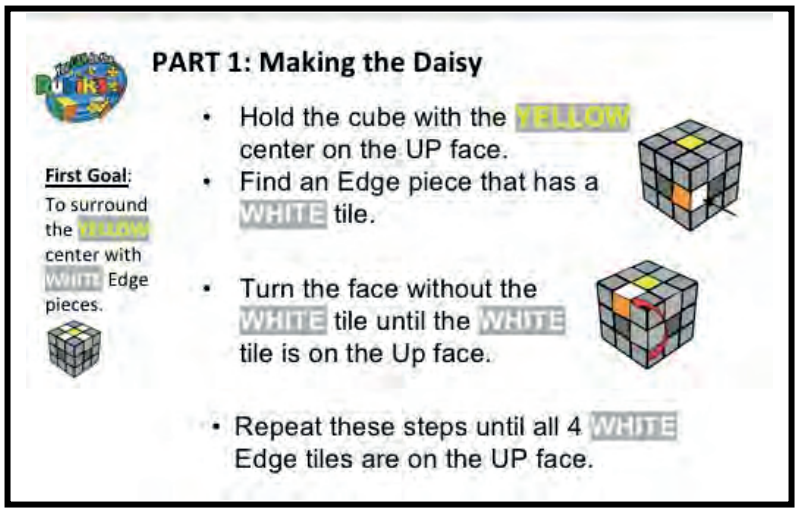
Have students determine how to get the:

- GREEN tile of the GREEN / RED Edge piece on the UP face. (F turn)
- RED tile of the GREEN / RED Edge piece on the UP face. (Li turn)
- YELLOW tile on the BOTTOM layer of the LEFT face (either Li F or L B) Another way of moving this tile is shown on slide 16.



There are many resources that state that making the daisy is intuitive. While many solvers find it fairly easy, slides 15 & 16 offer some tips for those who are getting stuck. If students are still struggling, go back to slides 11 & 12 to get a better feel for how the Edges move.

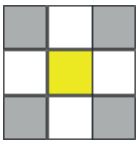
Slides 14 -16



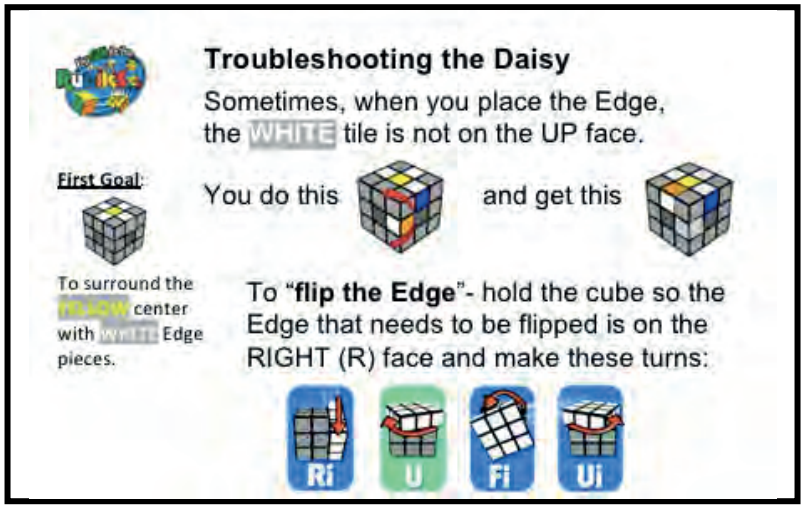
To make the Daisy, the YELLOW face must be the UP face. Now that you have the YELLOW Center, you need the WHITE petals.

Using what they learned about how Edge pieces move, students will locate the Edge pieces with WHITE tiles and put the WHITE tiles on the UP face surrounding the YELLOW Center.

View of UP face when all WHITE Edge tiles are in place



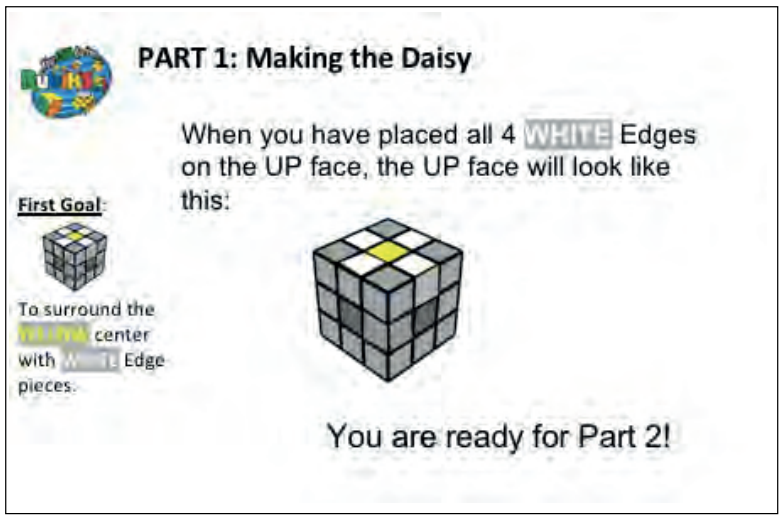
HINT: Students may need to turn the TOP layer before moving an Edge piece so that they don't lose a WHITE tile that is in the correct position.



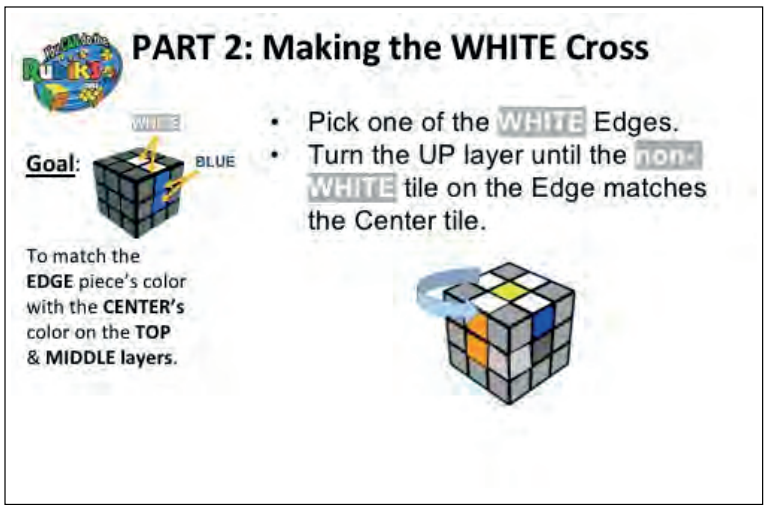
Sometimes, the Edge piece is moved to the TOP layer but the WHITE tile is not on the UP face. This algorithm for "flipping an edge" is a handy one to know.

You might have students follow the algorithm for any Edge piece and then repeat the algorithm to see how the Edge piece returns to its original state. This may give them a better sense of what the algorithm does as well as extra practice executing the algorithm.

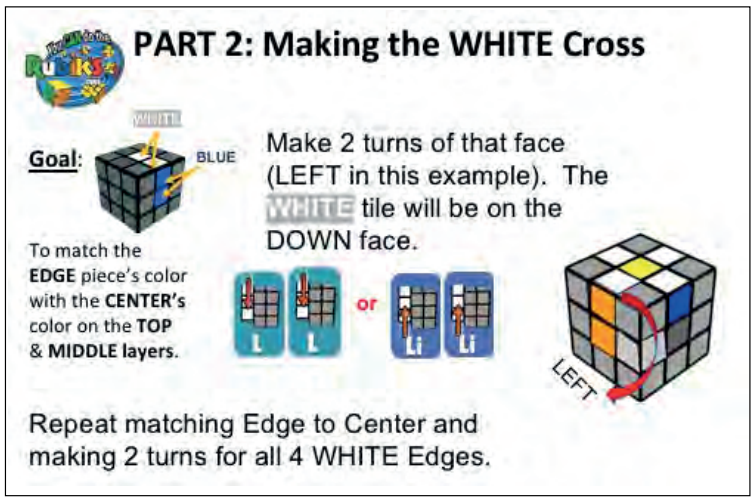
Slides 17 - 19



At this point, the non-WHITE Edge pieces may not match their corresponding Centers. That's one of the goals of Part 2.



The daisy is on the UP face for Part 2. It doesn't matter which Edge you choose first. The important step is to match the non-WHITE tile of the Edge piece to its matching Center tile. In the example given, the ORANGE Edge tile is matched to its ORANGE Center by turning the UP face.

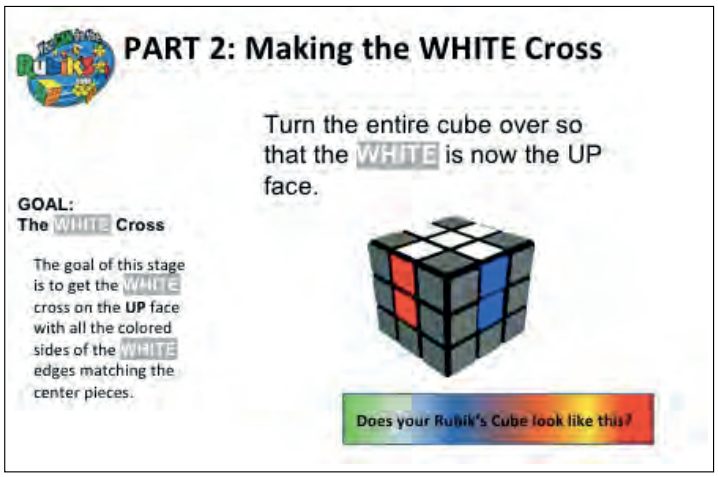


Once the non-WHITE Edge is matched with its Center, 2 turns of that face (in the example, the ORANGE face) will move the WHITE tile to the DOWN face.

One at a time, match Edges to Centers and make 2 turns for each 4 the Edge pieces surrounding the YELLOW Center. Now, the petals of the daisy are being moved to the DOWN face.

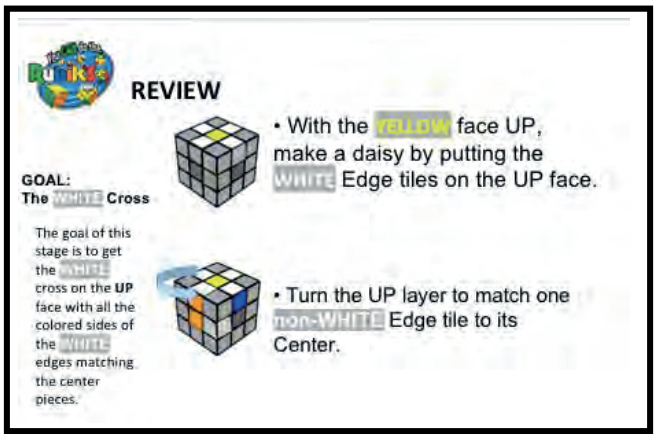
HINT: Have students place the flat of their palm on the face with the matching Edge & Center. This will help them know which face to turn.

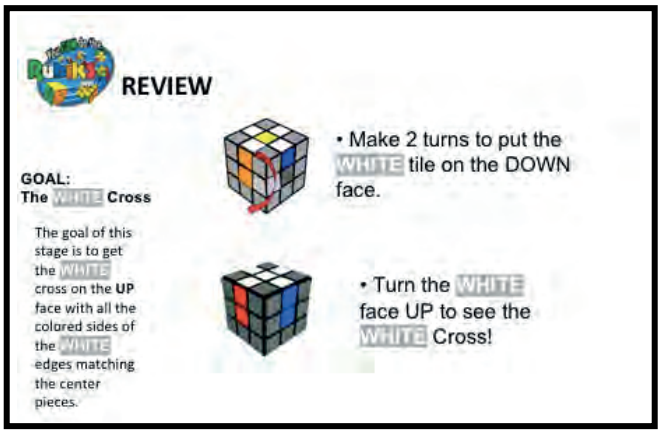
Slides 20 - 21

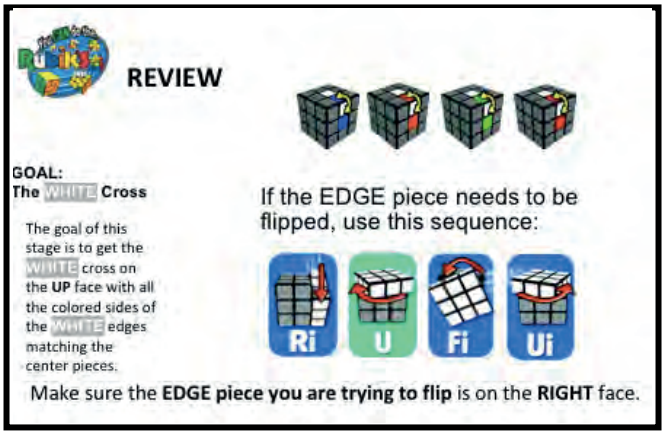


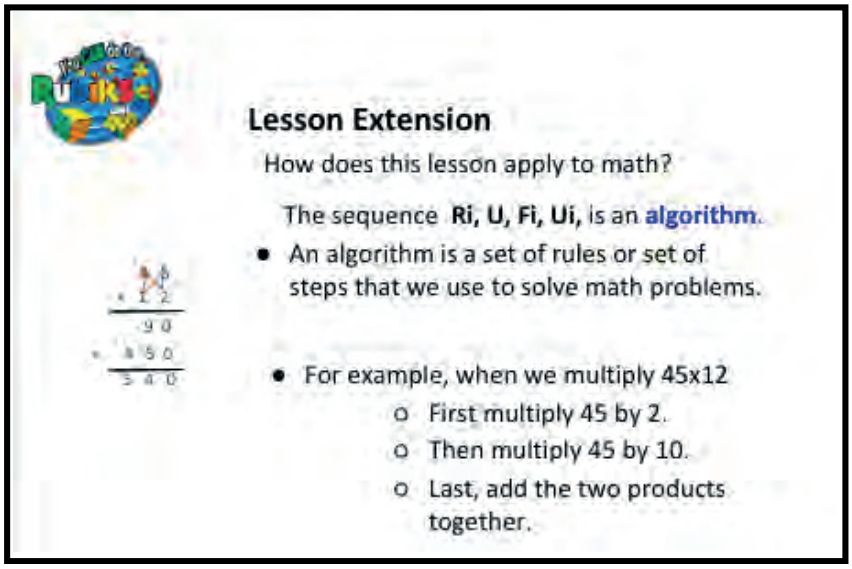
Review: Slides 22 - 24

These slides could be printed as a reference for students, perhaps in a learning center.







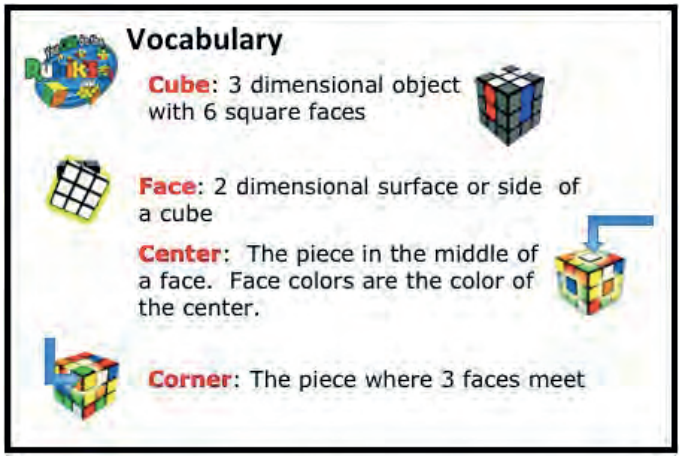


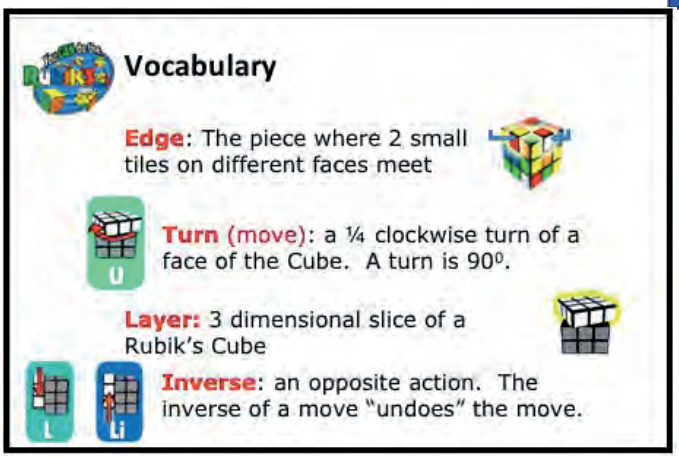
Math Connection: Slide 25

Any computational algorithm could be used here.

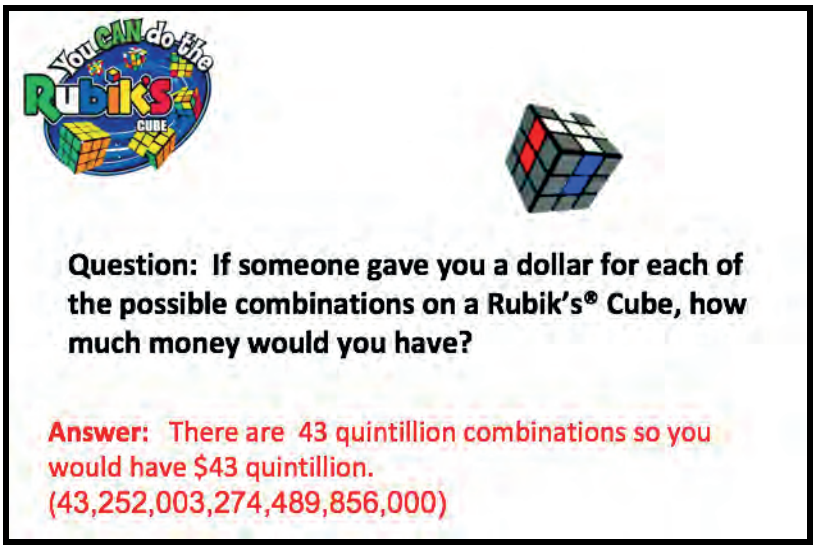
The slides on this page could be part of a class book, student journal, research project, or bulletin board.

Vocabulary: Slides 26 - 27





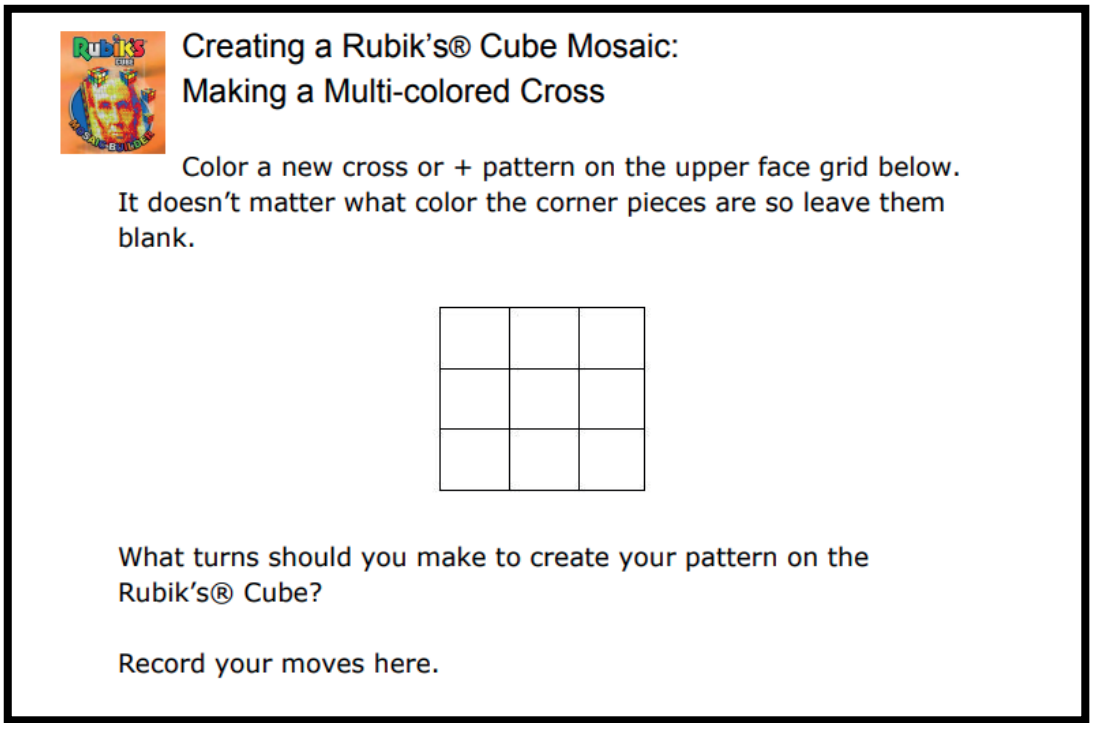
Trivia: Slide 28



Reading large numbers and rounding to a specific place are great math connections here, too.

Did you know we have digital presentations that accompany this guide? Go to our website and select the **EDUCATORS** tab, then **Teaching to Solve**.
https://www.youcandothecube.com/educators/

You can also have your students practice using the skills for making the WHITE Cross with one of several lessons on our website that utilize the same skills to create other patterns. Go to our website and select the **EDUCATORS** tab, then choose **MATH and STEM lessons**.



Creating a Rubik's® Cube Mosaic:
Making a Multi-colored Cross

Color a new cross or + pattern on the upper face grid below. It doesn't matter what color the corner pieces are so leave them blank.

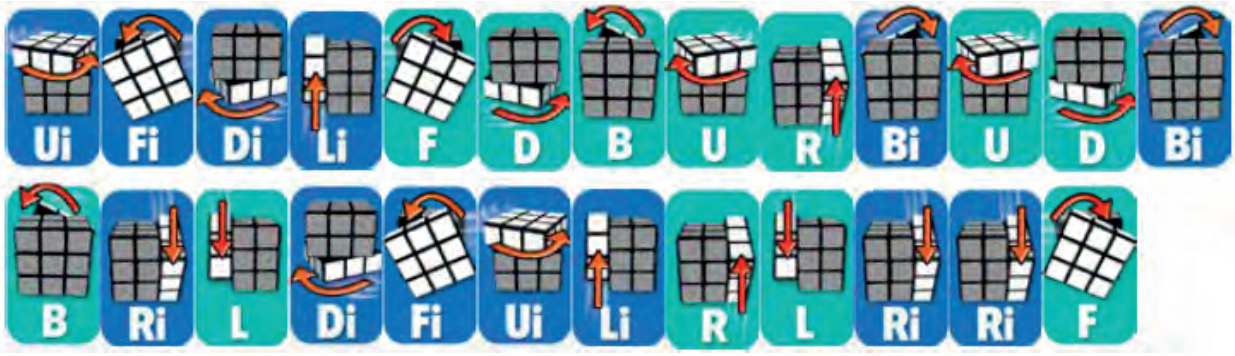
What turns should you make to create your pattern on the Rubik's® Cube?

Record your moves here.

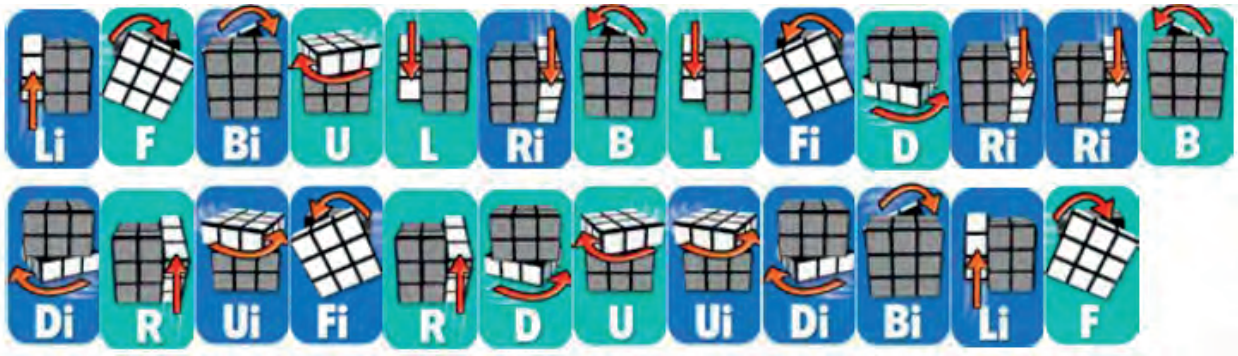
SCRAMBLING PRACTICE

Use the following sequences to practice scrambling your Rubik's Cube.

Sequence A - Will everyone's Cube look the same after this scramble? Why or why not?



Sequence B



Sequence C - Record your own 25 turns to scramble a cube.

____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

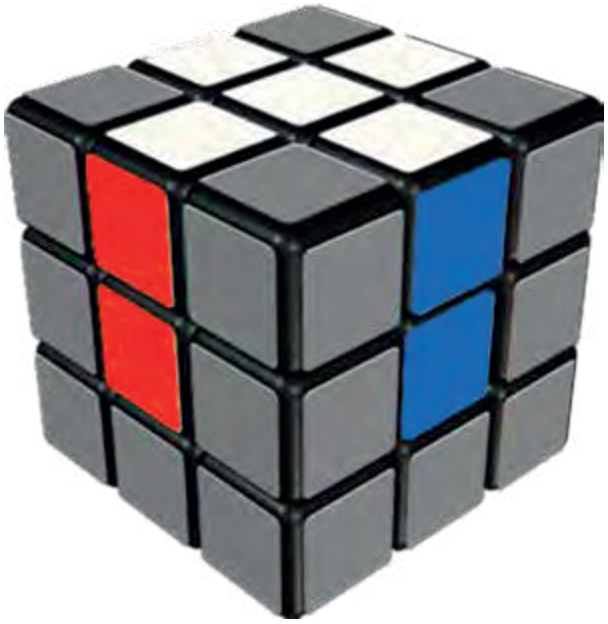
____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____ ____

____

Any 25 turns of a Rubik's Cube is called a scramble. The goal is to mix the cube up as much as possible. Some scrambles might be better than others. What would be a bad scramble? Why?

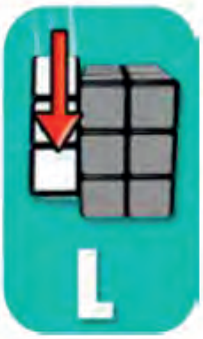
How well do you know the cube?

Here's a Rubik's Cube with a completed WHITE CROSS. The gray tiles could be any of the Rubik's Cube colors. It doesn't matter for this activity.



Color the cube below so that it shows what the hidden sides of the cube above look like.

QUARTER TURN REFERENCE SHEET



The WHITE Corners

Lesson 3

GOAL:
The WHITE Corners

The goal of this stage is to get the WHITE corners on the **UP** face with the **TOP** layer of each face matching the center piece.

Do you see the letter T on the RED, BLUE, ORANGE, and GREEN sides?

CONTENT STANDARDS & SKILLS: LESSON 3

Grade	Common Core	NCTM
K-2	CCSS.MATH.CONTENT.K.G.B.4 Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/"corners") and other attributes (e.g., having sides of equal length).	Operations & Algebraic Thinking: ● Recognize, describe and extend patterns ● Analyze how patterns are generated Geometry: ● Use visualization, spatial reasoning & geometric modeling to solve problems.
3-5	CCSS.MATH.CONTENT.1-3.G.A. Reason with shapes and their attributes.	Number & Operations: ● Understand meanings of operations and how they relate to one another Algebra: ● Analyze change in various contexts Geometry: ● Predict and describe the results of sliding, flipping, & turning two-dimensional shapes
6-8	CCSS.MATH.CONTENT.8.G.A.1 Verify experimentally the properties of rotations, reflections, and translations.	Number & Operations: ● Understand and use inverse relationships Geometry: ● Precisely describe two- and three-dimensional objects using their attributes ● Create & critique inductive & deductive arguments concerning geometric ideas & relationships

Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Please modify your presentation as best meets the needs of your students.

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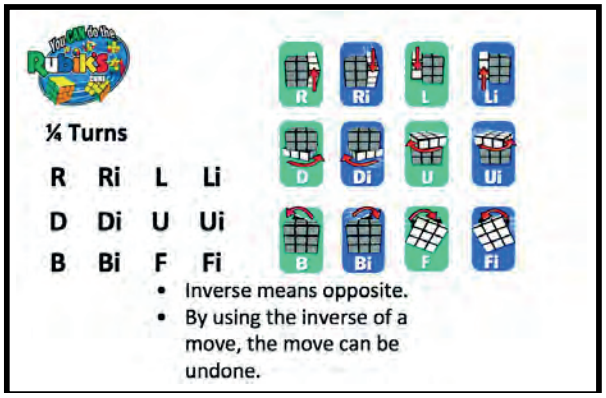
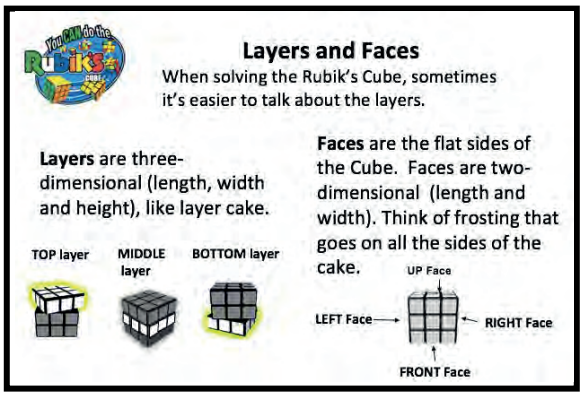
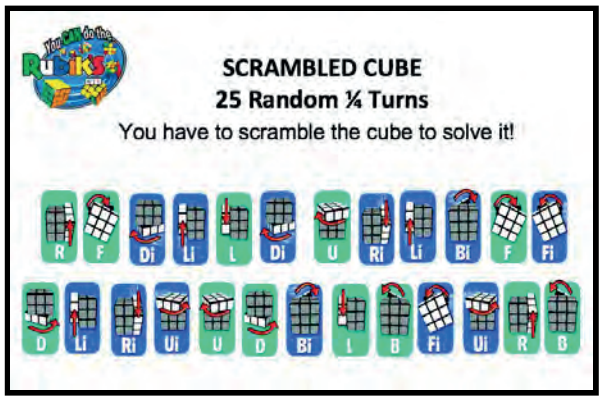
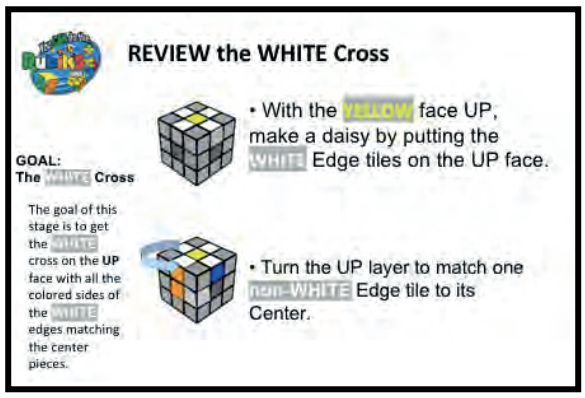
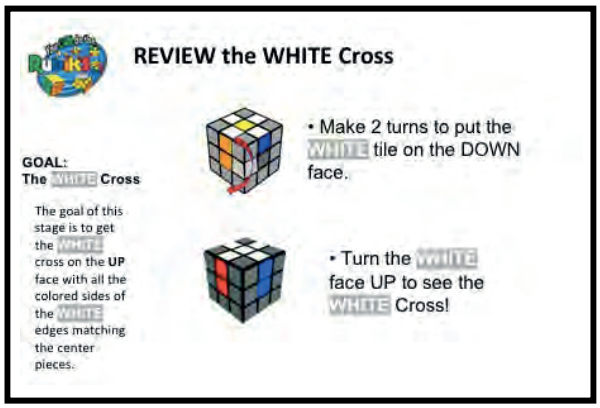
Review: Slides 3 - 8

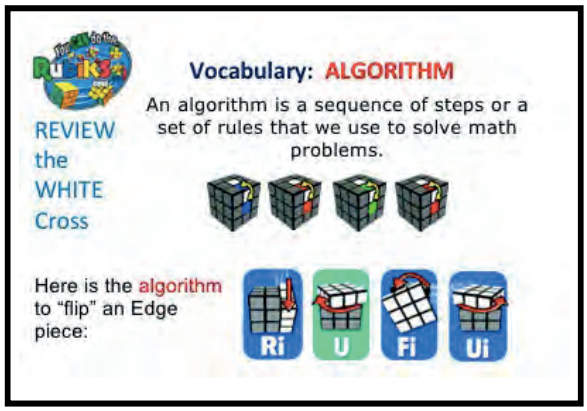






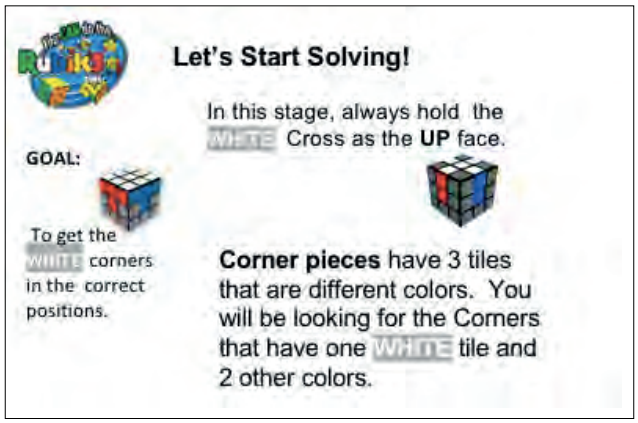






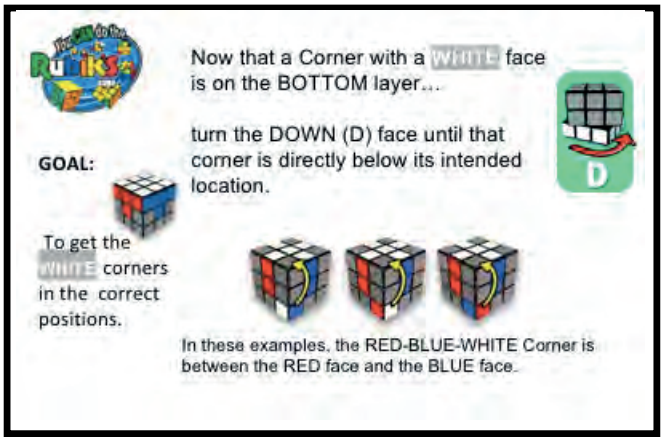
With each subsequent lesson, there is a greater need to check that the previous stage remains intact as the next stage is executed. Look for the reminders: **Check to see that you still have the cross!**

Lesson Content: Slides 9 - 18



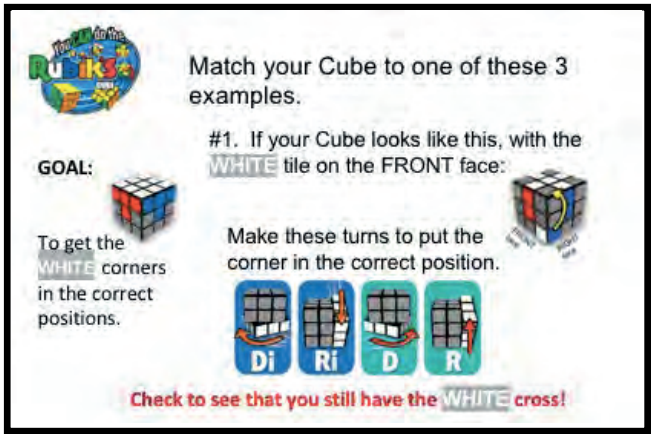
Have students use 3 fingers (thumb, index and middle fingers) to locate the CORNER. It does not matter which of the faces the tiles are on.

Slides 12 - 15



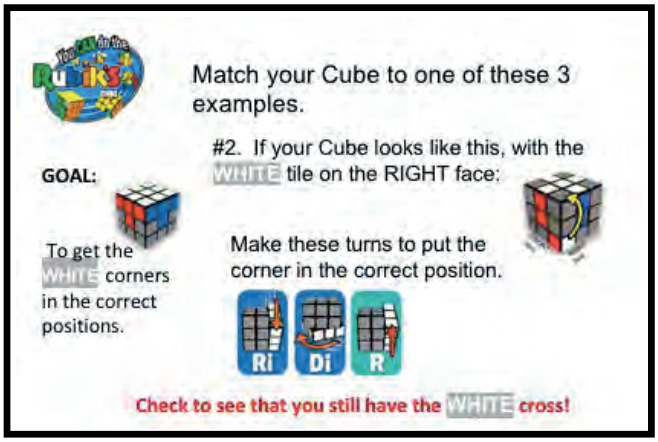
How do you know where the intended position is? The non WHITE tiles should match the CENTER tiles of the faces the CORNER is between. It does not matter which of the CORNER's tiles is on which face.

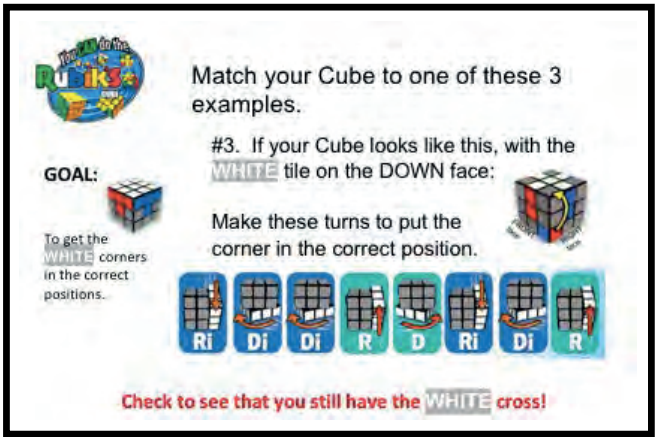
In this example, the WHITE-BLUE-RED Corner is between the RED and the BLUE faces.



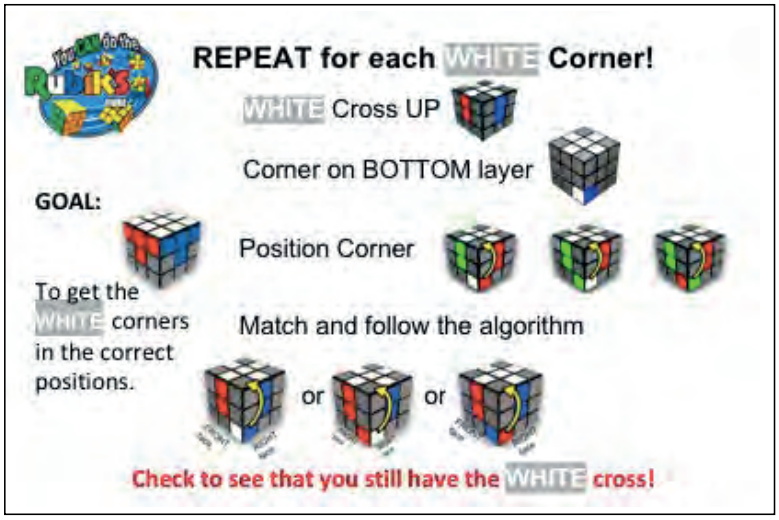
The location of the WHITE face on the corner tile determines the correct match. Make sure students are holding the Cube with the matching corner on the RIGHT face in the Bottom layer.

CAUTION: If the WHITE Cross has come undone, students will need to go back to Lesson 2/Stage 2 to recreate the WHITE Cross.

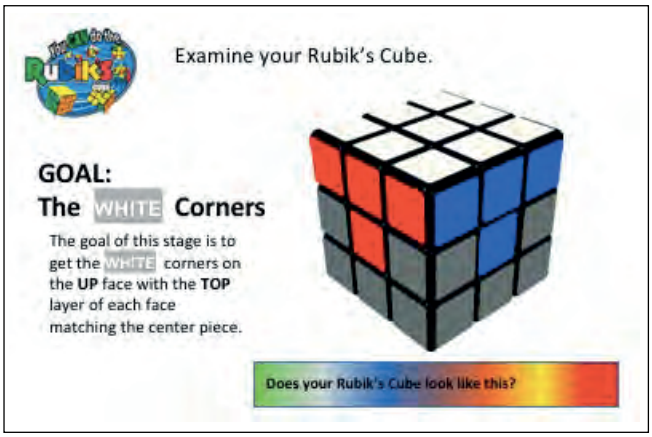




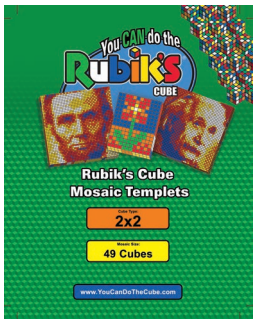
Slides 16 - 18



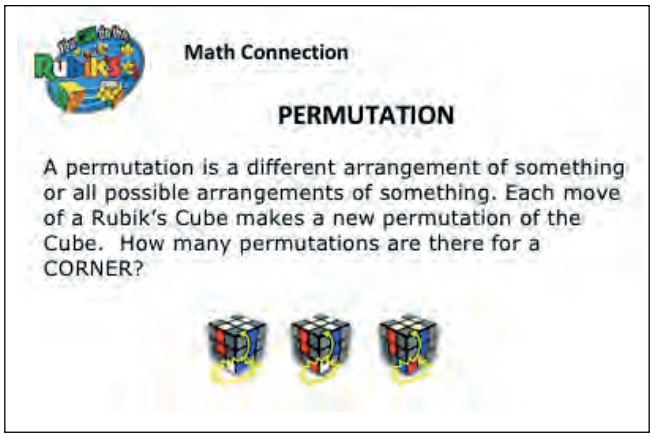
These steps will be repeated to place the WHITE Corners on the UP face. This slide could be printed for student notebooks or a bulletin board along with slide 22. Slide 22 shows the 3 algorithms on one slide.



Now that your students have solved the WHITE face, have them practice these skills by creating a mosaic with Rubik's Cubes. We have ready-made templates or you can create your own. Go to our website and select the MOSAICS tab to take advantage of all our resources. **https://www.youcandothecube.com/build-mosaics-with-rubiks-cubes/**



Math Connection: Slides 19 - 20



A permutation of 3 "objects" (WHITE, BLUE, RED tiles) would result in 6 arrangements.

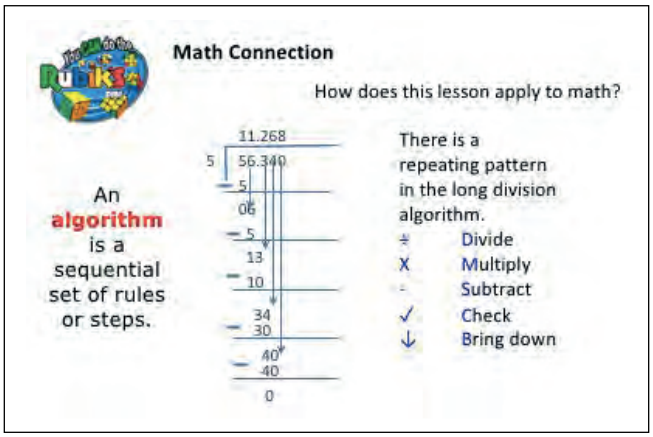
3 • 2 • 1

Tile choices for the first position

Tile choices for the second position

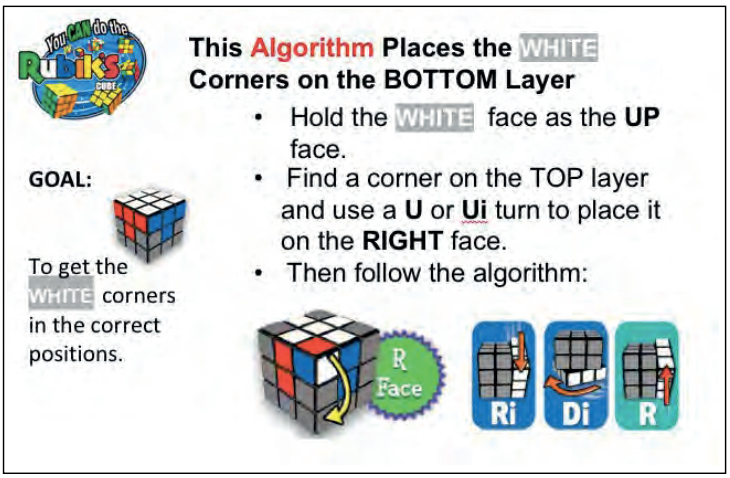
One tile left for the third position

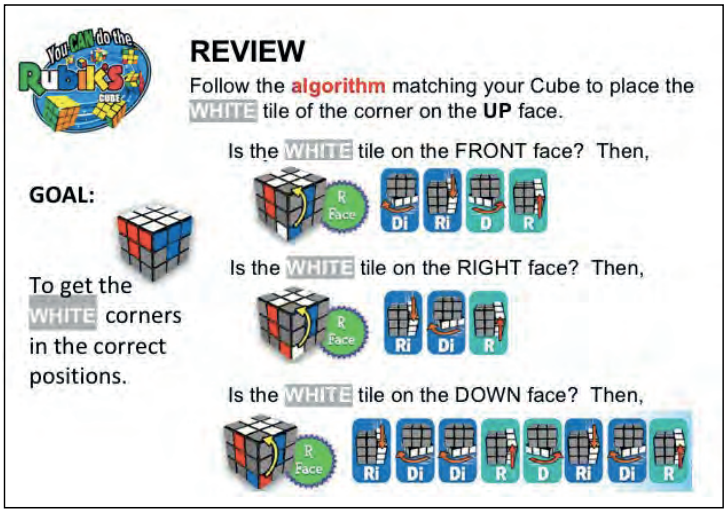
Why are there only 3 ways the Rubik's corner can be positioned? (The other color positions are not possible on a Rubik's Cube. For example, it is not possible to have the WHITE face FRONT, RED face RIGHT, and BLUE face DOWN in the lower RIGHT corner of a Rubik's Cube.)



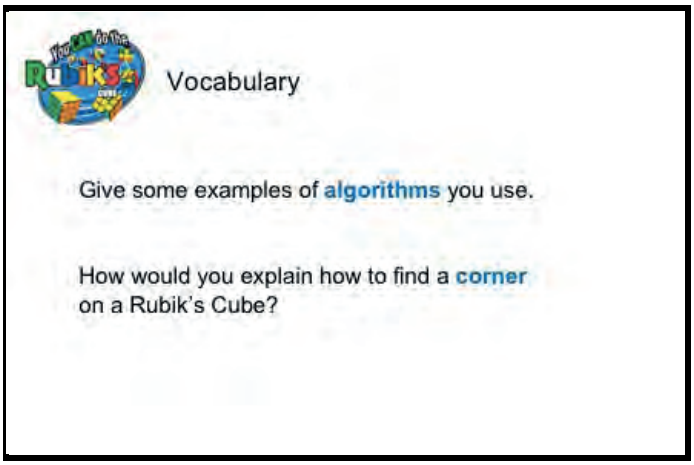
Any computational algorithm could be used.

Review: Slides 21 - 22 These slides could be printed as a reference for students, perhaps in a learning center.





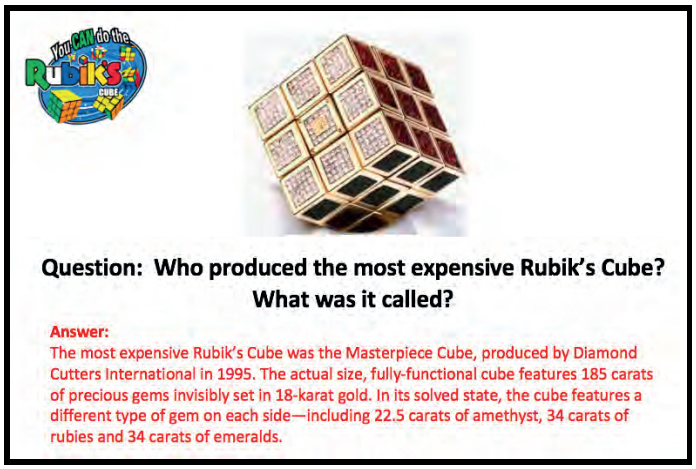
Vocabulary: Slide 23



Encourage students to have a broad definition of algorithm. What they do to get ready for school each morning could be an algorithm.

Use **vertex** in place of corner when appropriate.

Trivia: Slide 24



Answer:
The most expensive Rubik's Cube was the Masterpiece Cube, produced by Diamond Cutters International in 1995. The actual size, fully-functional cube features 185 carats of precious gems invisibly set in 18-karat gold. In its solved state, the cube features a different type of gem on each side—including 22.5 carats of amethyst, 34 carats of rubies and 34 carats of emeralds.

The MIDDLE Layer

Lesson 4

GOAL:

The Middle Layer

The goal of this stage is to solve the Middle Layer while keeping the WHITE face intact. (the WHITE cross and WHITE corners)

For this lesson, you will hold the cube so the YELLOW face is the **UP** face and the WHITE face is the **DOWN** face. But first, let's review.

CONTENT STANDARDS & SKILLS: LESSON 4

Grade	Common Core	NCTM
K-2	CCSS.MATH.CONTENT.1-3.G.A. Reason with shapes and their attributes.	**Algebra** ● Recognize and describe patterns **Geometry** ● Use visualization, spatial reasoning & geometric modeling to solve problems
3-5	CCSS.MATH.CONTENT.1-3.G.A. Reason with shapes and their attributes. CCSS.MATH.CONTENT.3.NF.A.1 Understand a fraction 1/*b* as the quantity formed by 1 part when a whole is partitioned into *b* equal parts; understand a fraction *a*/*b* as the quantity formed by *a* parts of size 1/*b*. CCSS.MATH.CONTENT.3.NF.A.3 Explain equivalence of fractions in special cases, and compare fractions by reasoning about their size. CCSS.MATH.CONTENT.4.G.A.3 Recognize a line of symmetry for a two-dimensional figure as a line across the figure such that the figure can be folded along the line into matching parts. Identify line-symmetric figures and draw lines of symmetry.	**Number & Operations** ● Understand meanings of operations and how they relate to one another **Algebra** ● Analyze change in various contexts **Geometry** ● Predict and describe the results of sliding, flipping, and turning two-dimensional shapes
6-8	CCSS.MATH.CONTENT.6.NS.C.5 Understand that positive and negative numbers are used together to describe quantities having opposite directions or values… CCSS.MATH.CONTENT.7.NS.A.1.A Describe situations in which opposite quantities combine to make 0. CCSS.MATH.CONTENT.8.G.A.1 Verify experimentally the properties of rotations, reflections, and translations.	**Number & Operations** ● Understand and use inverse relationships **Geometry** ● Create and critique inductive and deductive arguments concerning geometric ideas and relationships

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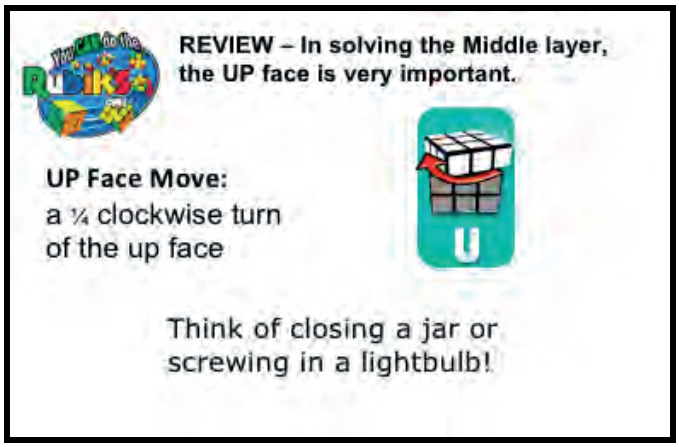
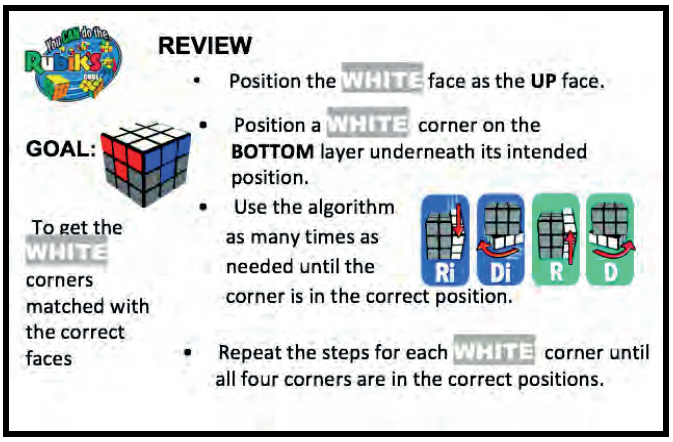
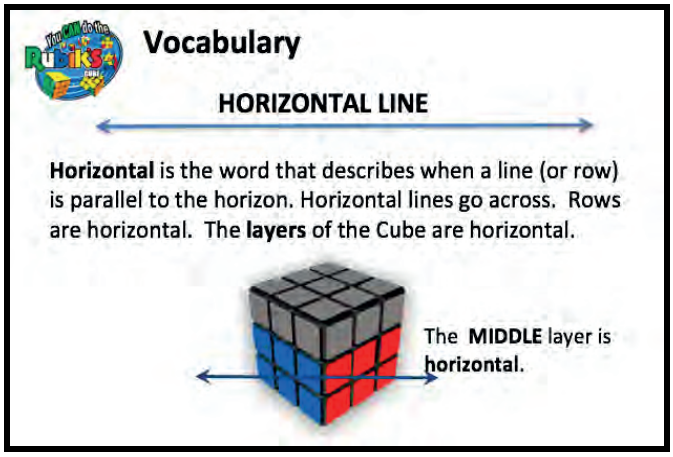
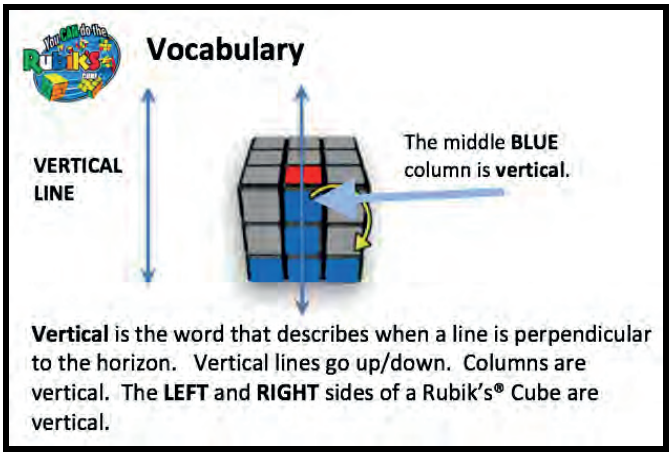
Review: Slides 3- 6

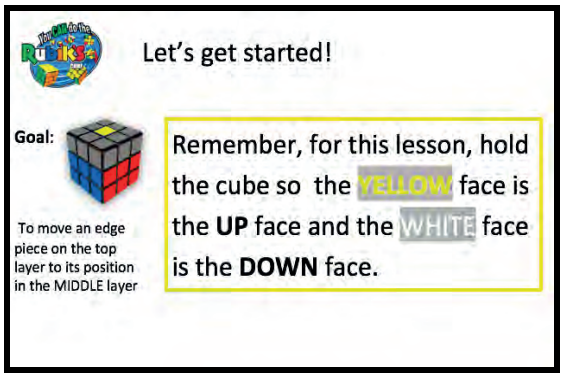


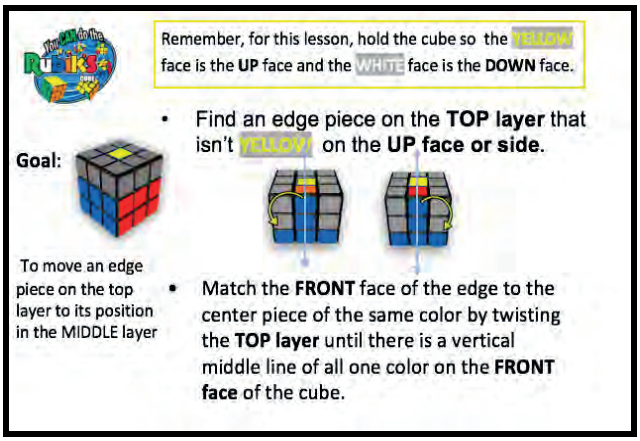




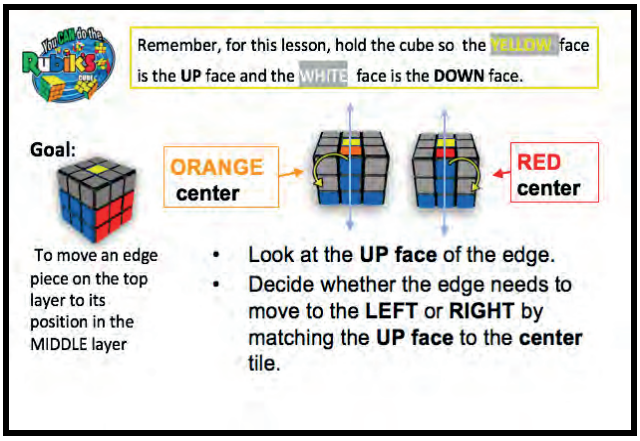


Content: Slides 7 - 11

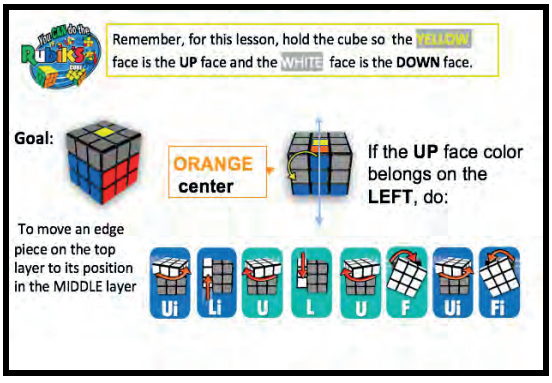


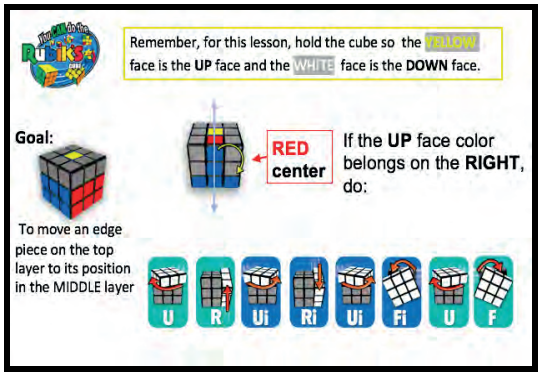


With the **YELLOW** center on the **UP** face, scan the **TOP** layer for an **EDGE** piece that has no **YELLOW** tiles. Once one **EDGE** piece has been located, match the color of the lateral face (not the UP face) of this tile with the color of the **CENTER** of the lateral face. If there are no **EDGE** pieces without **YELLOW** tiles, check **TROUBLESHOOTING** p. 6 of this guide.



Now look at the **UP** face of the tile you matched to a **CENTER**. The color of the **UP** tile will determine whether to follow the **LEFT** algorithm or the **RIGHT** algorithm. The algorithms for moving the cube to the **LEFT** or **RIGHT** are essentially the same. Because **LEFT** and **RIGHT** are inverses, the algorithms use inverse moves. Once students have seen the algorithm for moving the cube to the **ORANGE or LEFT** face, you may want to challenge them to provide the algorithm for moving the cube to the **RED or RIGHT** face.

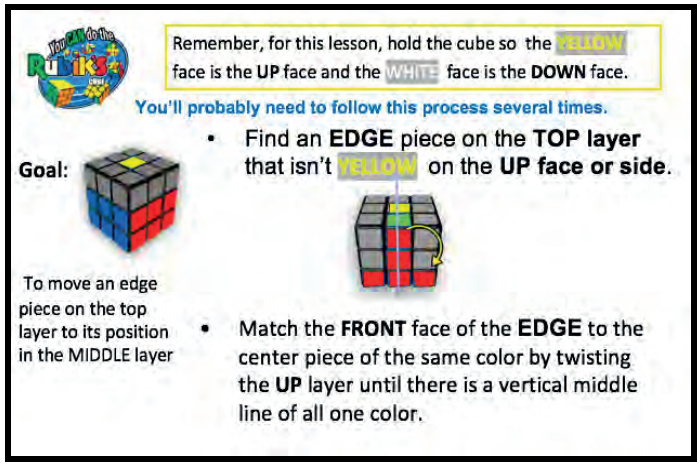


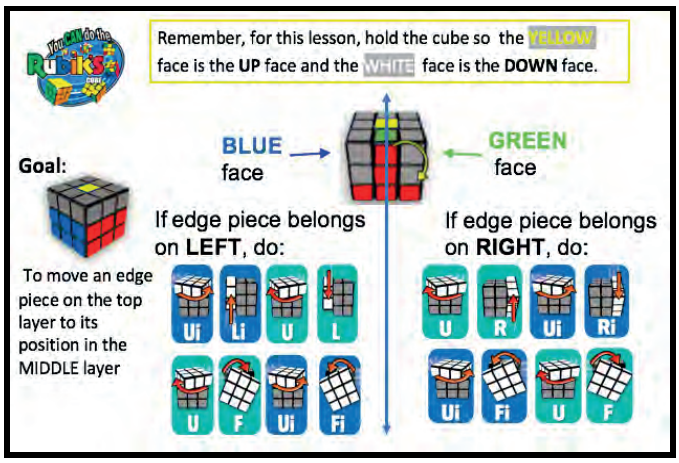


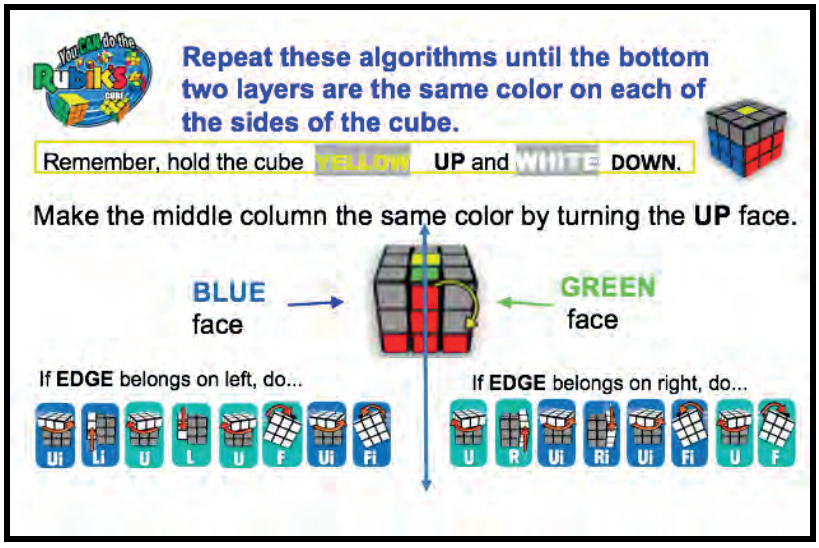
Slides 12 - 14

That's all there is to it! Repeat these steps until the bottom 2 layers of the cube are solid colors.

- Find an **EDGE** piece on the **TOP layer/UP face** with no **YELLOW** tiles.
- Match the color of the "side" of the tile with a "side" face **CENTER** tile by twisting the **TOP** layer. You may want to remind students that this is a lightbulb or jar move.
- Look at the color of the **UP** face of the **EDGE** piece to decide whether the **EDGE** piece will move to the **LEFT** or the **RIGHT** face. Follow the appropriate algorithm.

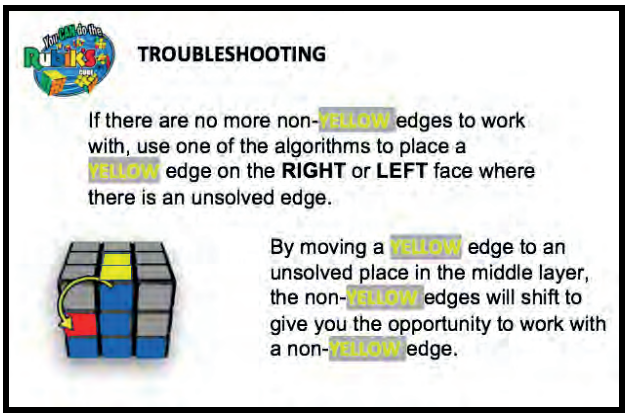


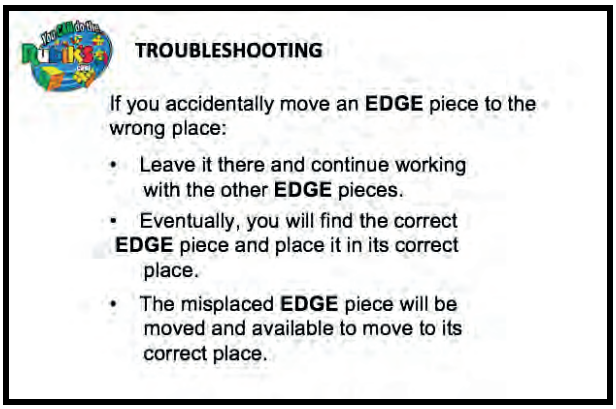


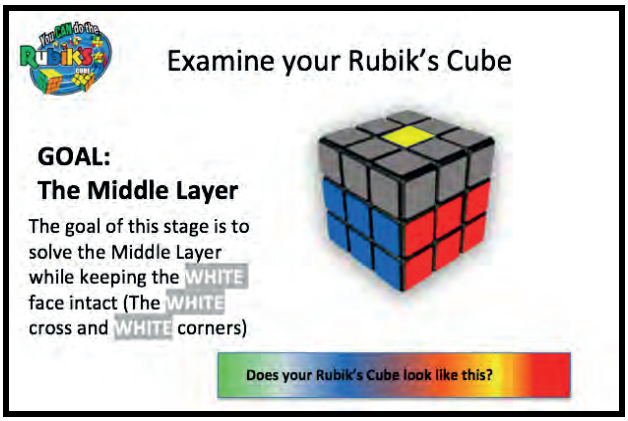


Slides 15 - 18

Sometimes there are no **EDGE** pieces on the **TOP** layer with no **YELLOW** tiles. In this case, you will need to follow either the **LEFT** or the **RIGHT** algorithm once. This will "swap" a misplaced **EDGE** piece for the **EDGE** piece in the **TOP** layer. (see slide image) Now, there will be an **EDGE** piece on the **TOP** layer with no **YELLOW** tiles.

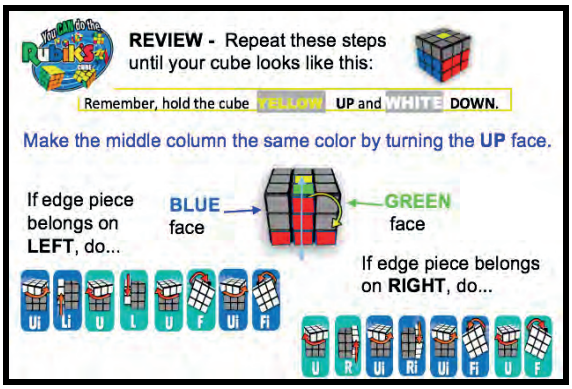


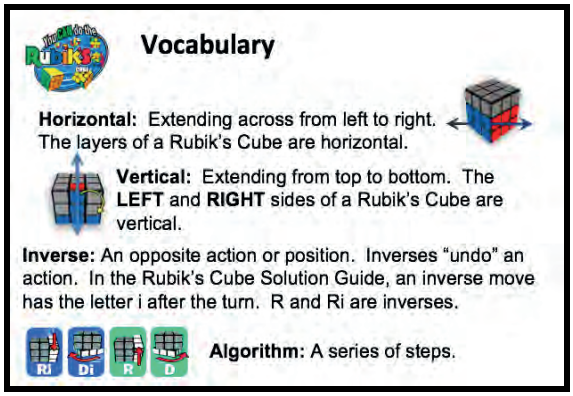




Review: Slides 19 - 20

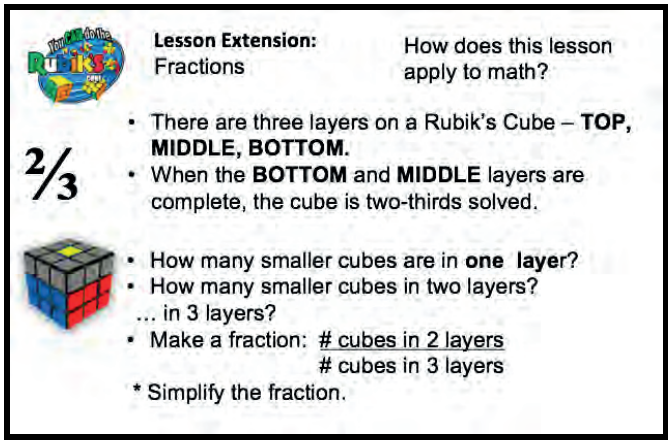
This slide could be printed as a reference for students, perhaps in a learning center.





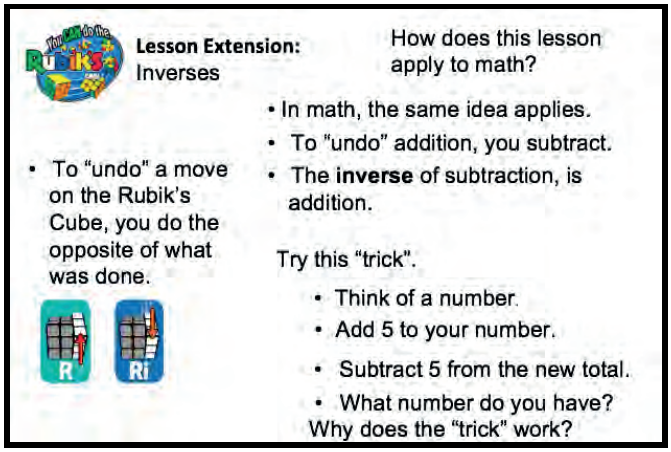
Math Connections: Slides 21 - 25

There are several math connections for this lesson, a brief look at fractions and a longer look at inverses and solving equations.



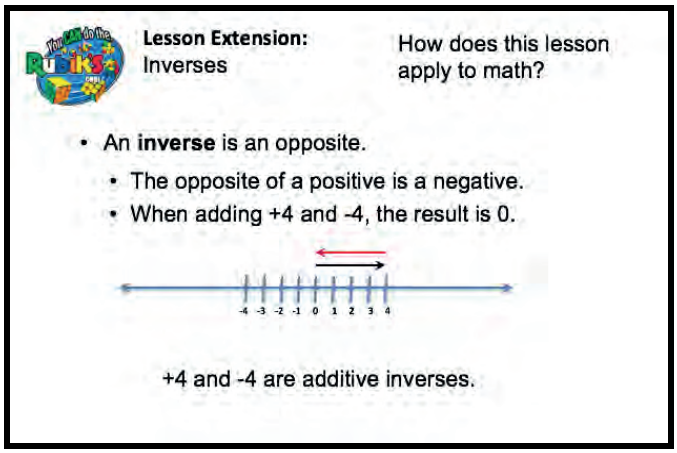
Fractions

- Explore fractions on a single face of the Cube. (i.e. What fraction of the face is RED?)
- Challenge students to make 2 faces of a cube ⅓ RED.
- Some fractions can't be made on a Rubik's Cube. Which ones? Why?
- You can't make more than ⅙ of the Cube RED because only one face of the Cube is RED. However, more than ⅙ of a face could be RED. What is the greatest number of sides you can consider to make a fraction where RED is greater than ½? ⅓?

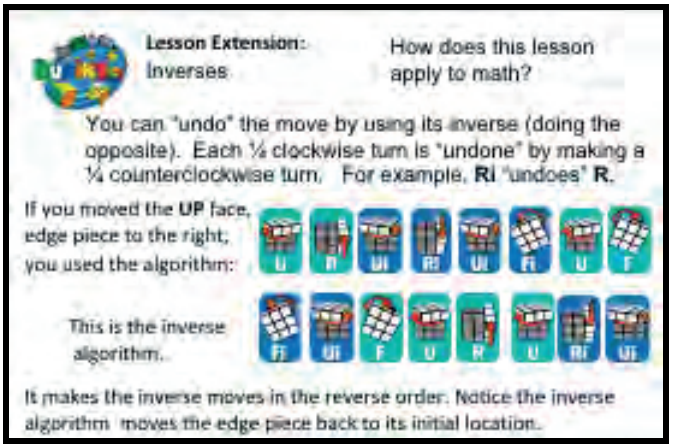


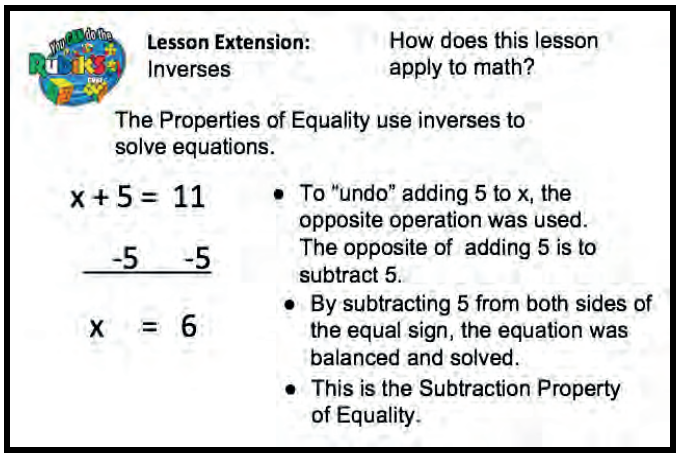
Inverses

- Inverses are opposites. What other opposites are there?
- Have students create other number tricks.

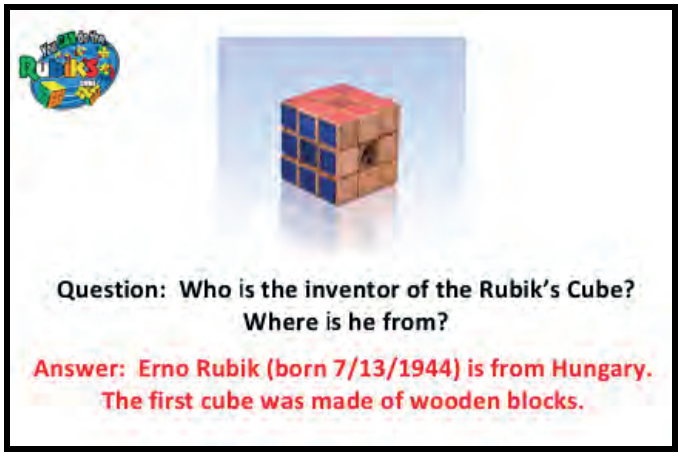


- Zero is the identity element for addition because the additive inverses have a sum of 0. Does a Rubik's Cube have an identity element? What would it be?
- Identity elements are often included in the properties of a set. What other properties does a Rubik's Cube have?





TRIVIA: Slide 26



Solving Equations

- Have students create a Rubik's sequence and then challenge a friend to write the inverse sequence.
- Have students highlight the inverses in a sequence.
- Mathematics has an order of operations. Does changing the order of the steps in the sequence change the results?

- Challenge students to write a Rubik's Cube sequence in a way that mimics the equation solving process.

The YELLOW Face

Lesson 5

GOAL:
The YELLOW Face

The goal of this stage is to place all the YELLOW tiles on the **UP** face.

CONTENT STANDARDS & SKILLS: LESSON 5

Grade	Common Core	NCTM
K-2	CCSS.MATH.CONTENT.1-3.G.A. Reason with shapes and their attributes.	**Algebra** ● Recognize and describe patterns **Geometry** ● Use visualization, spatial reasoning & geometric modeling to solve problems
3-5	CCSS.MATH.CONTENT.4.G.A.3 Recognize a line of symmetry for a two-dimensional figure as a line across the figure such that the figure can be folded along the line into matching parts. Identify line-symmetric figures and draw lines of symmetry.	**Algebra** ● Analyze change in various contexts **Geometry** ● Predict and describe the results of sliding, flipping, and turning two-dimensional shapes
6-8	CCSS.MATH.CONTENT.8.G.A.1 Verify experimentally the properties of rotations, reflections, and translations.	**Geometry** ● Create and critique inductive and deductive arguments concerning geometric ideas and relationships

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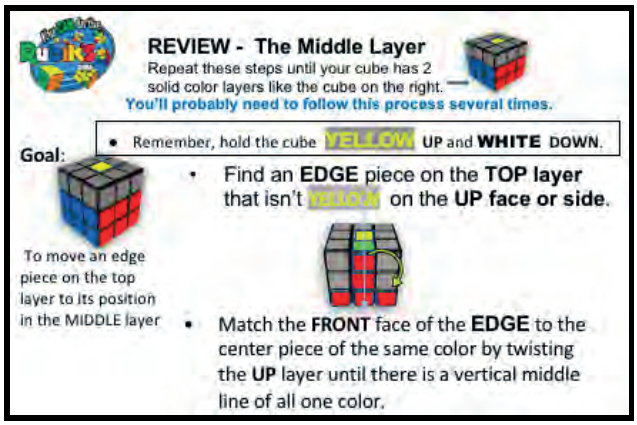
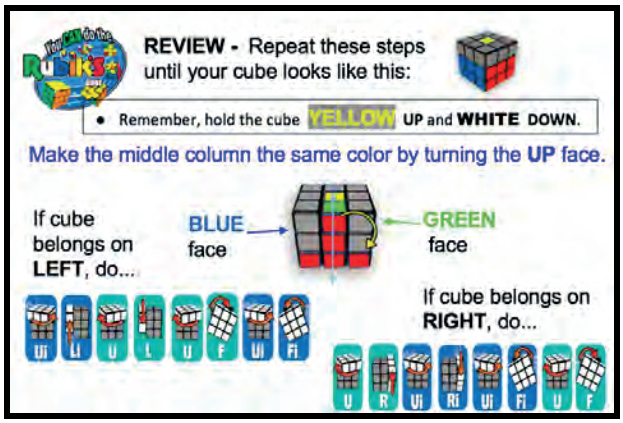
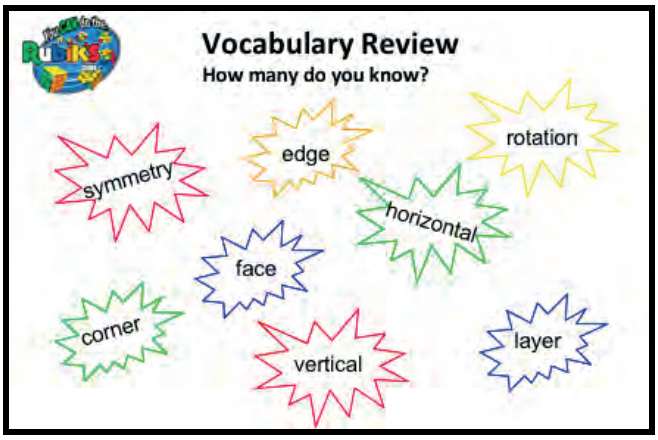
Review: Slides 3 - 5

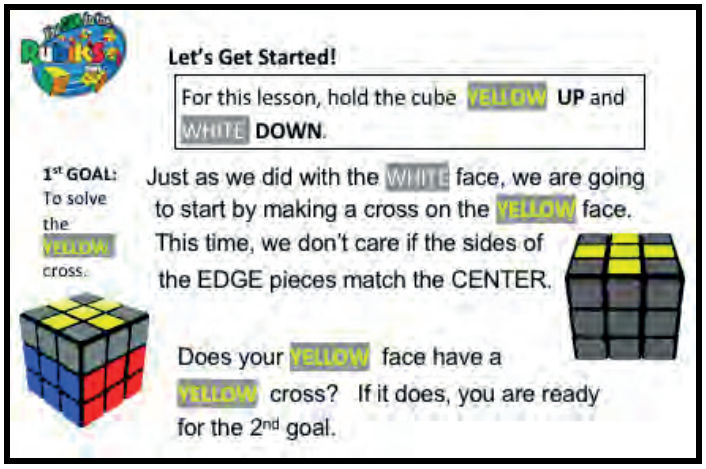




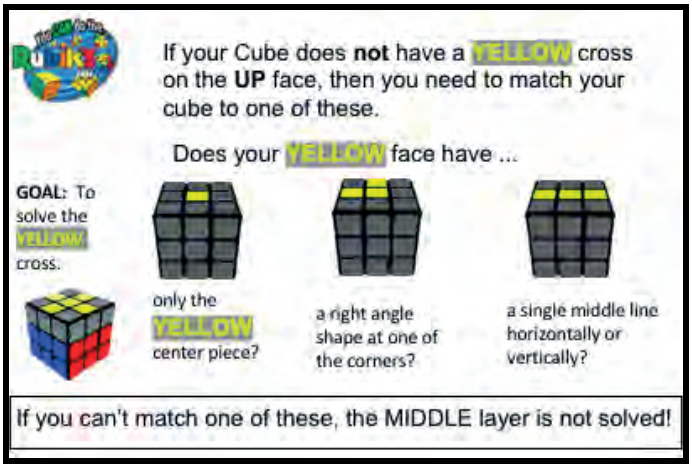


This is a static slide. Review terms as you see fit. Basic suggestions below:
Symmetry: a fold line where one half matches the other half exactly
Edge: where 2 faces meet
Rotation: a turn (90^0 on a Rubik's Cube)
Corner: where 3 faces meet
Face: the side of a cube
Horizontal: going across
Vertical: going up/down
Layer: a horizontal section (layer cake)

Lesson Content: Slides 6 - 22



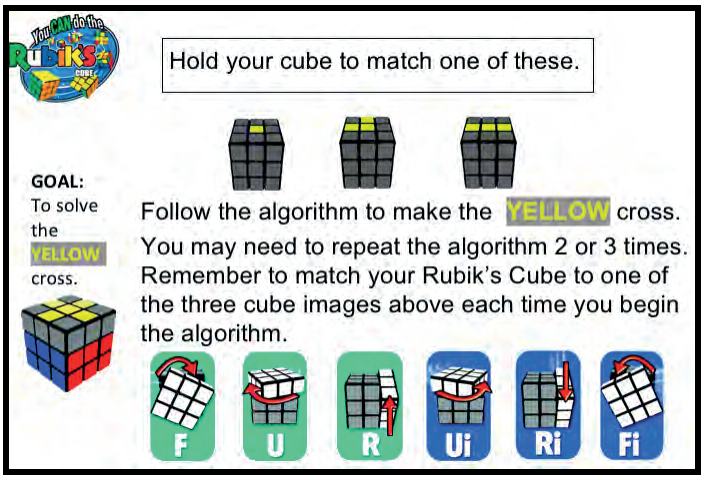
There are two parts to solving the YELLOW face. The first part is to solve for the YELLOW cross. The second part is to make the UP tile of the corners YELLOW. The corners will be matched to their correct FACE in Lesson 6, the final stage.



Just as with the WHITE cross, focus on the **EDGE pieces**. If there is not already a YELLOW cross, students will have a YELLOW "backwards L" in the upper left corner (middle image), a row of YELLOW tiles (right image), or neither (left image). Students should find the best match and hold the cube as shown.

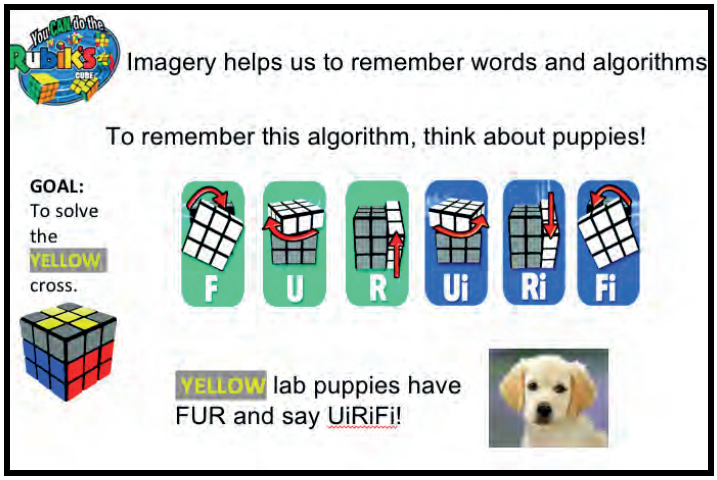
There will be 0, 2,or 4 YELLOW EDGE pieces. If there are 1 or 3 YELLOW EDGE pieces, then the MIDDLE Layer has not been solved. The MIDDLE Layer must be solved to continue.

Slides 8 - 11

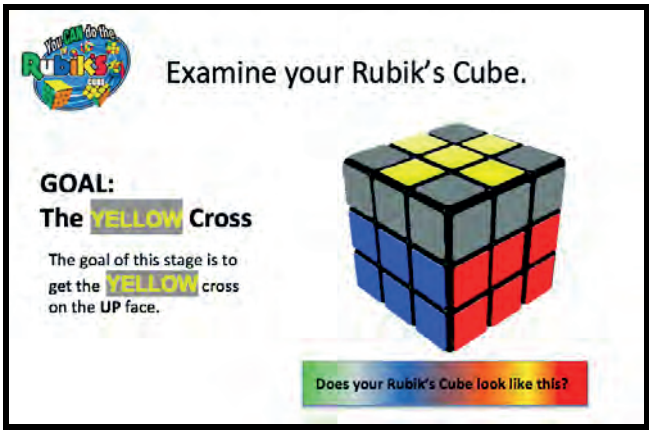


For the stages of solving YELLOW face, the orientation of the cube is very important. Students should hold their Rubik's Cubes to match one of the 3 examples.

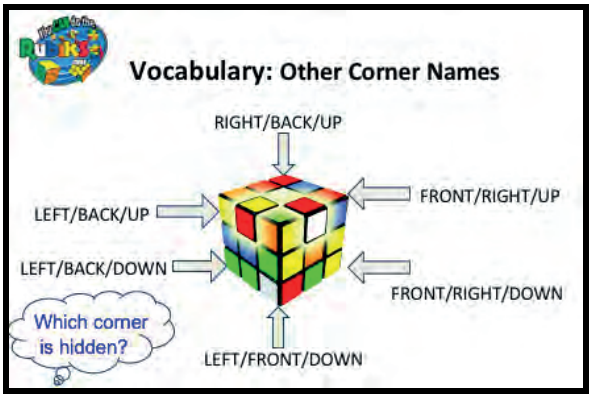
HINT: Keeping the Cube on the table or desk may help students attend to the orientation of the cube which is an important concept as they solve.



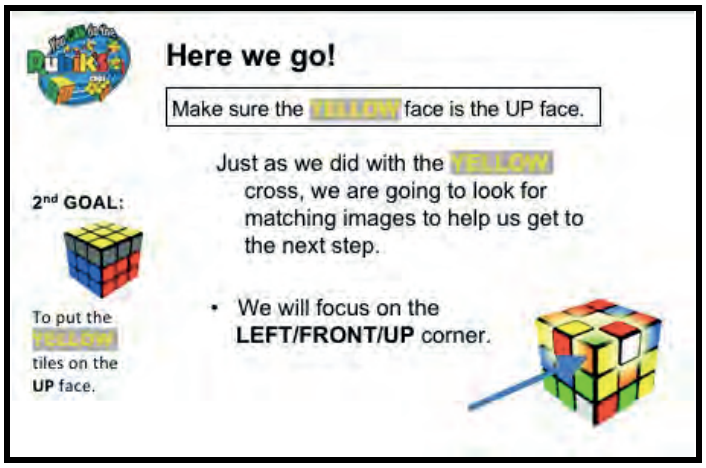
Orientation is key! Each time the algorithm is completed, the cube must be turned to match one of the 3 examples. Then, the algorithm is repeated.



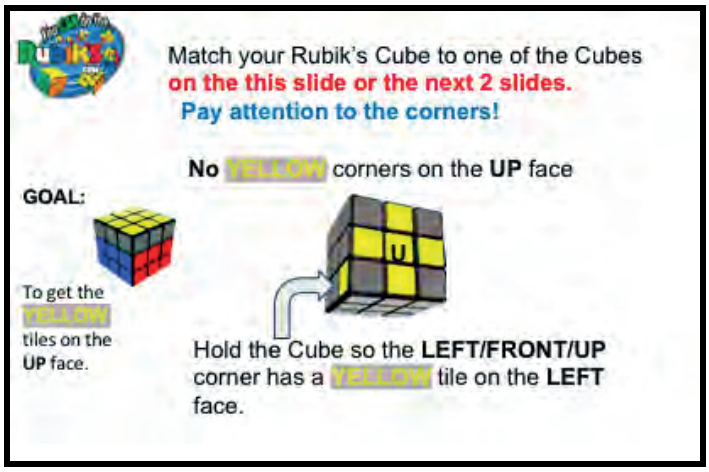
Slides 12 - 15



The LEFT/FRONT/UP corner is the key to placing YELLOW corner tiles on the UP face to complete the YELLOW face. (The answer to "which corner is hidden?" is RIGHT/BACK/DOWN.)

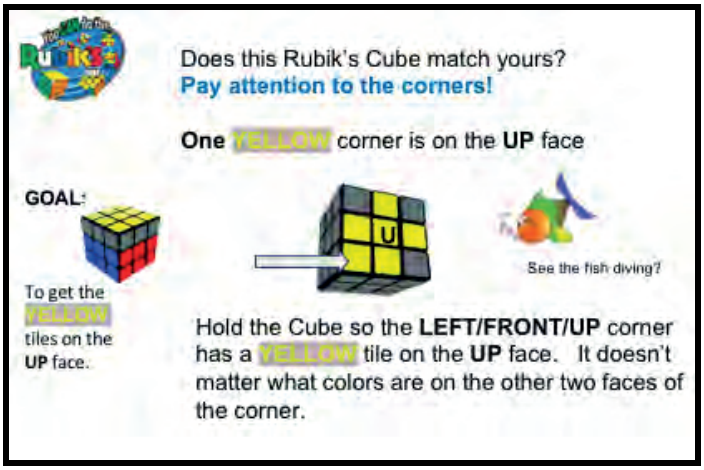


The next 4 slides show the matching positions. Each time you repeat the algorithm for the corners, students will need to match the placement of the YELLOW tile on the LEFT/FRONT/UP corner, depending on the number of YELLOW tiles already on the corners of the UP face.



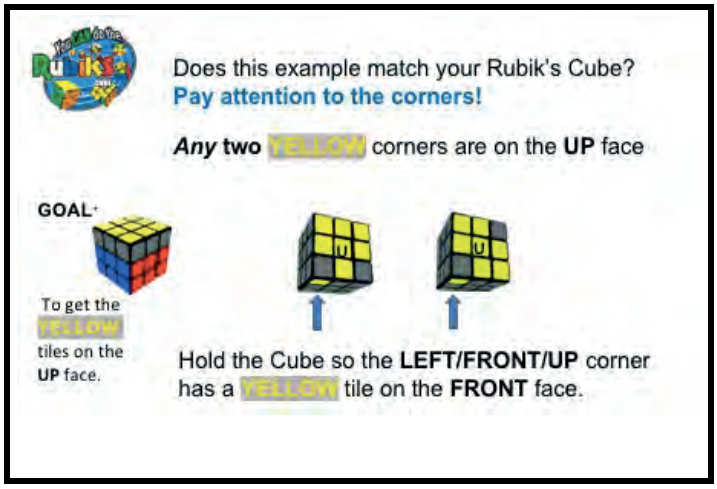
If there are **no** YELLOW corner tiles, turn the entire cube (the whole cube) until the LEFT/FRONT/UP corner has a YELLOW tile on the LEFT.

Slides 16 - 18

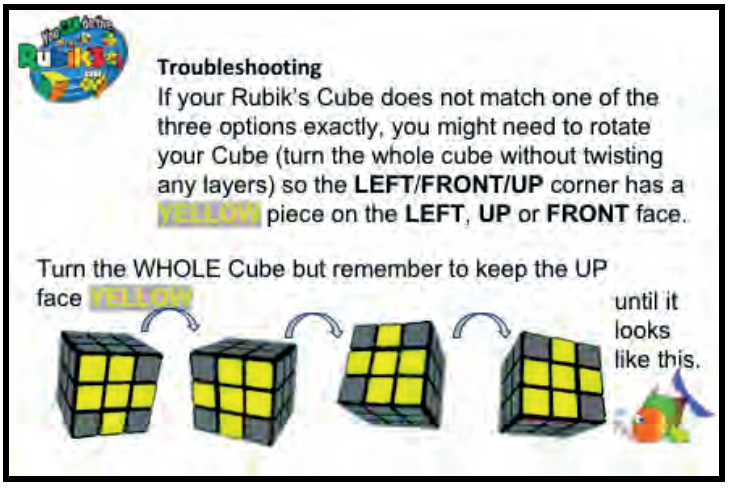


If there is **one** YELLOW corner tile, turn the entire cube (the whole cube) until there are no YELLOW tiles on any of the lateral sides of the LEFT/FRONT/UP corner.

HINT: Make the "fish" dive!



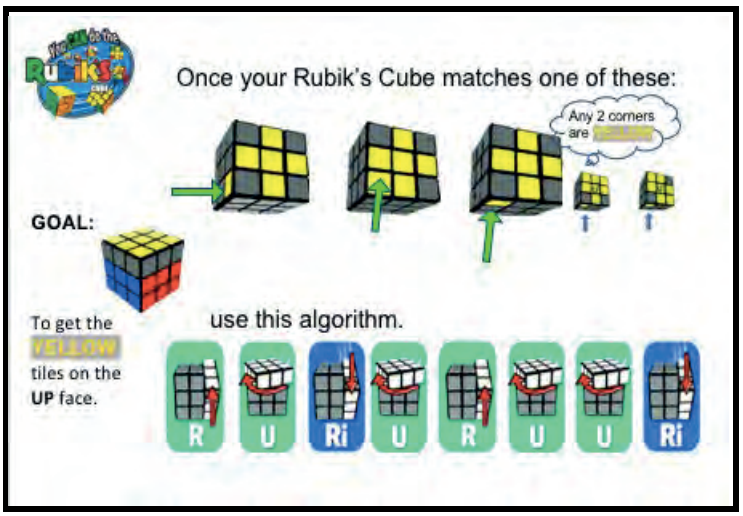
If there are **two** YELLOW corner tiles, turn the entire cube (the whole cube) until the FRONT of the LEFT/FRONT/UP corner is YELLOW. It doesn't matter where the 2 corner YELLOW tiles are.
HINT: Try this saying: If there's two, towards you.
(If there are 2 YELLOW corners, then a YELLOW tile on the LEFT/FRONT/UP corner faces you.)



This slide illustrates turning the whole cube to find the best match.

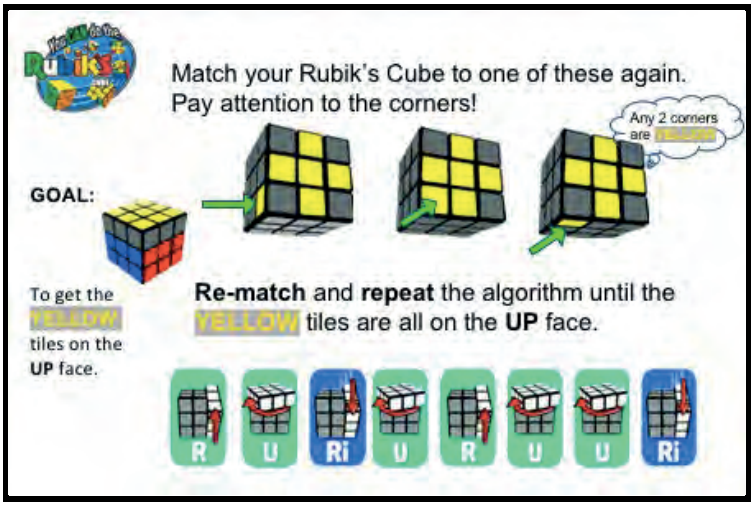
Note the image on the left is the starting position.

Slides 19 - 22



For the stages of solving YELLOW face, the orientation of the Rubik's Cube is very important. Students should hold their Cubes to match one of the 3 examples.

HINT: Keeping the Cube on the table or desk may help students attend to the orientation of the Cube, which is an important concept as they solve.

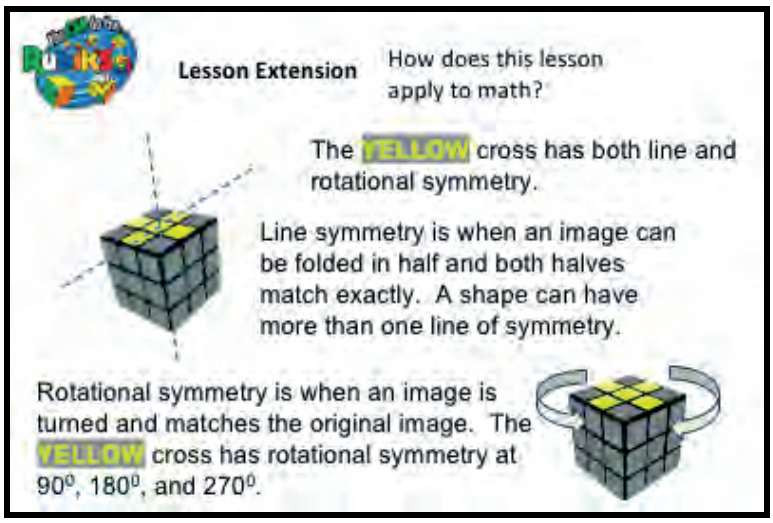


Orientation is key! Each time the algorithm is completed, the Cube must be turned to match one of the 3 examples. Then, the algorithm is repeated.

When the YELLOW face is complete, the lateral faces of the corners may not match their corresponding CENTER tiles. This last step will be accomplished in the next lesson.

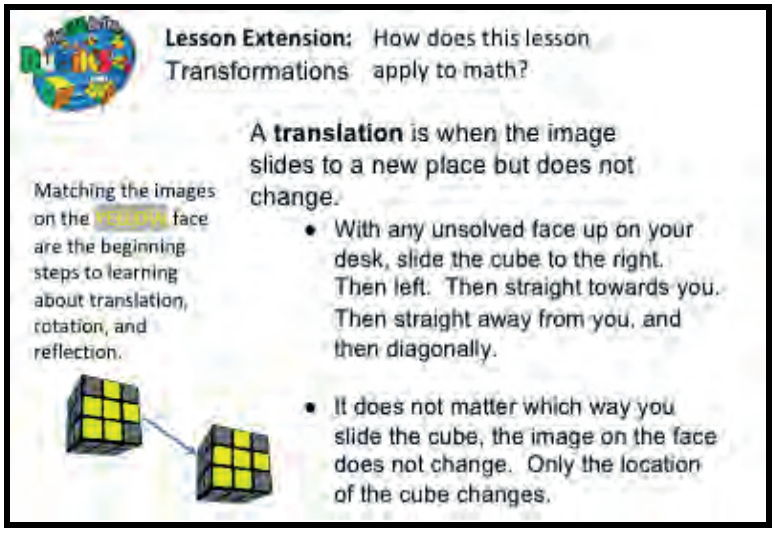
Math Connections - Slides 23 - 26

Generally, transformations involve moving an object in a specific way. After the transformation is complete, the result will be congruent to the original object. This may contradict students' non-math understanding of transformations such as the Transformer series of toys and cartoon characters.



Students may be familiar with line symmetry. Younger students could be challenged to find all the lines of symmetry on a single face. Explore how color influences lines of symmetry.

Older students may more easily grasp the concept of rotational symmetry by turning a Rubik's Cube. Challenge students to create other patterns on a face of a cube that have rotational symmetry. This may work well with partners (or with 2 cubes) so that one Cube remains in the same position while the second Cube is turned and compared to the first. Place the Rubik's Cube on a paper plate to turn it easily.



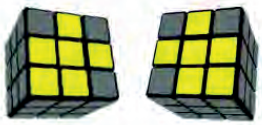
A translation or slide is a movement of an object along a line. This may seem obvious and the point can easily be lost. Have students think about where translations are seen in their world. Fabric and wallpaper with repeating patterns can be examples of translations. What would happen if the creator "stamped" a design without paying attention to whether or not the stamps were placed along a line? (The fabric or wallpaper may look crooked.) Students might try this using stamps or stickers to get a better sense of the concept of translation. Use a ruler as the slide line, the line along which the Rubik's Cube will move.

Lesson Extension: How does this lesson Transformations apply to math?

A **reflection** is when the image of one side looks the opposite of the other, like looking in a mirror.

Matching the images on the YELLOW face is the beginning step to learning about translation, rotation, and reflection.

- Try to find another student whose Rubik's Cube is a mirror image of your own.



- Draw the mirror image of your Rubik's Cube.

In a reflection, the image of the object is flipped over a line. Placing a small mirror or a piece of plexiglass between 2 cubes may help students see the line of reflection.

Lesson Extension: How does this lesson Transformations apply to math?

A **rotation** is when the cube or face turns around a point. Rotations are measured in degrees. A full rotation, back to the original position, would be 360 degrees.

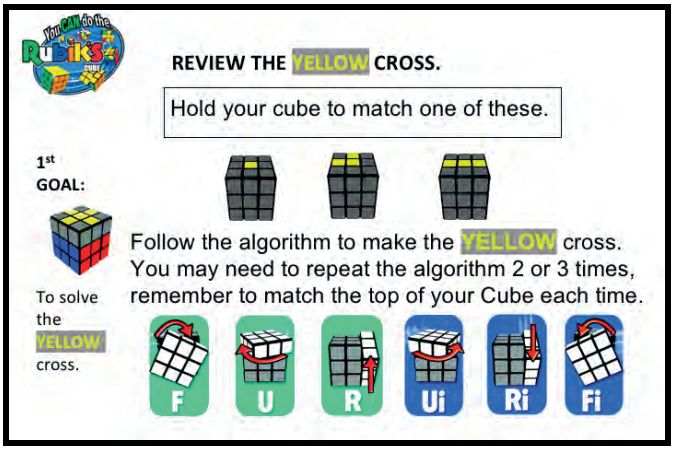
- You can try this by placing your Rubik's Cube on a piece of paper with any unsolved face up.
- Choose a corner and mark the spot on the paper with a dot.
- Keep the corner of the Cube the same distance from the dot as you move or rotate it around the dot.

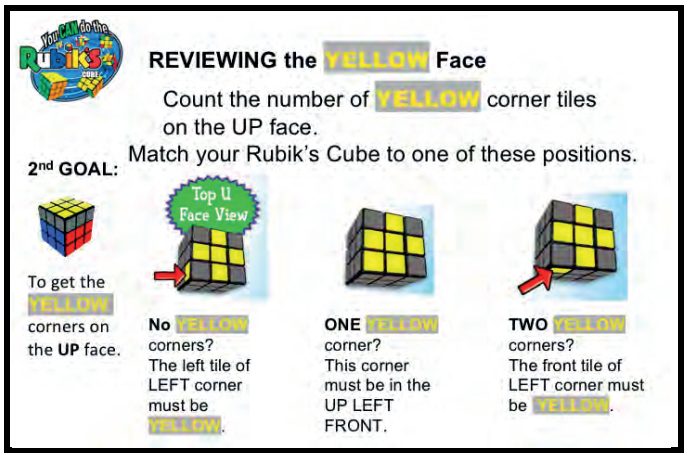
Rotations are turns of an object around a point, the center of rotation. Place the Rubik's Cube on a paper plate or Lazy Susan and mark the center of rotation. Place a finger on the center as the plate is turned.

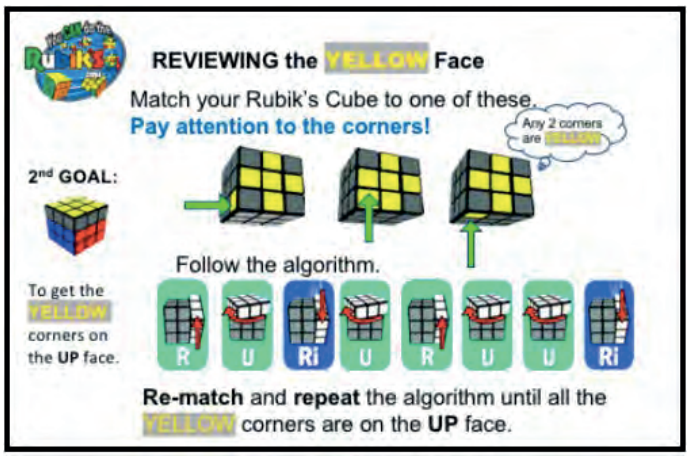
The plate could be placed on top of a larger piece of paper with an xy axis so that students could see the 90^0 turns.

Review: Slides 27 - 29

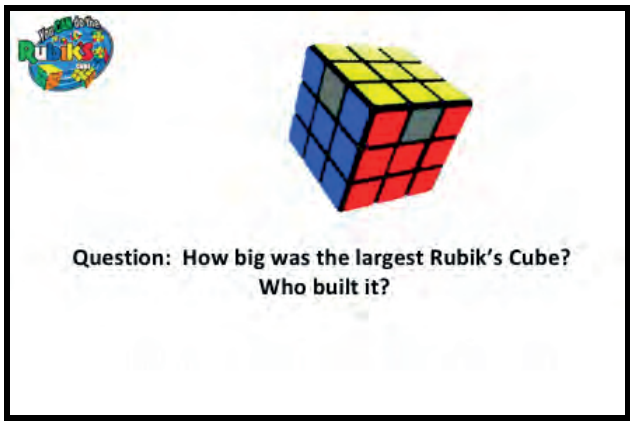
These slides could be printed as a reference for students, perhaps in a learning center.

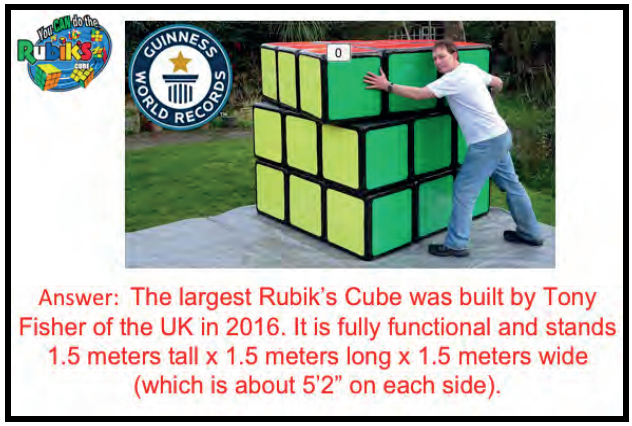






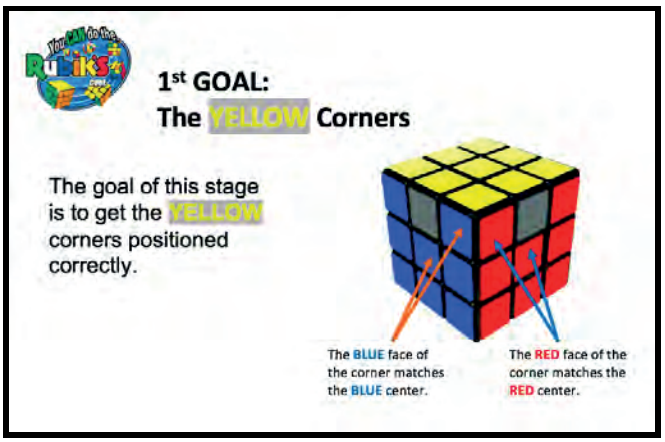
TRIVIA: Slide 30-31





Lesson 6

Positioning the YELLOW Corners & Edges

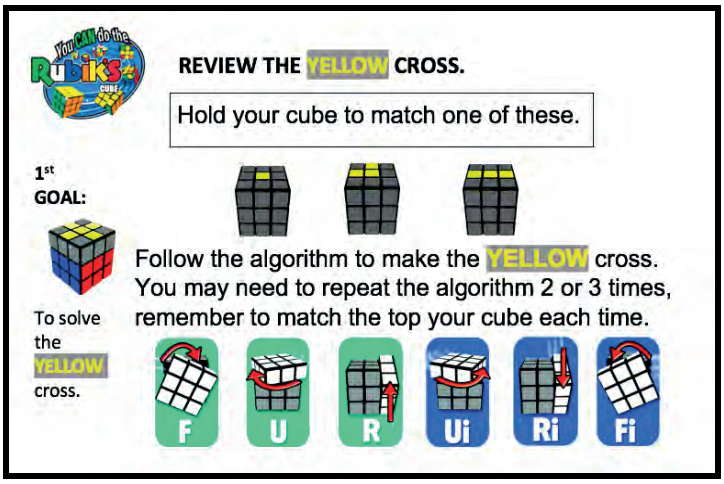


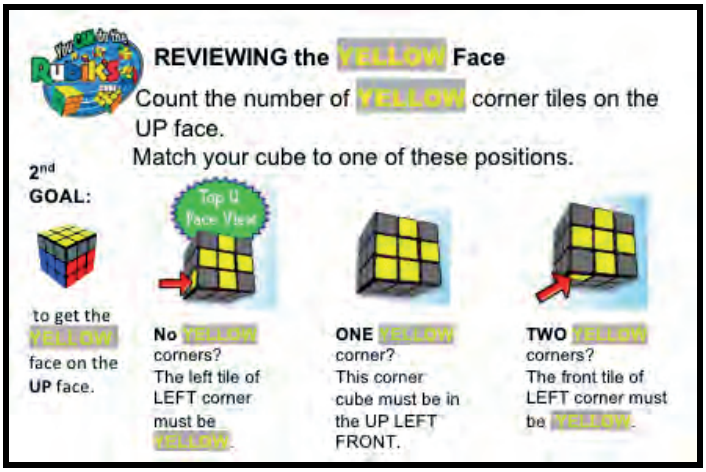
CONTENT STANDARDS & SKILLS: LESSON 6

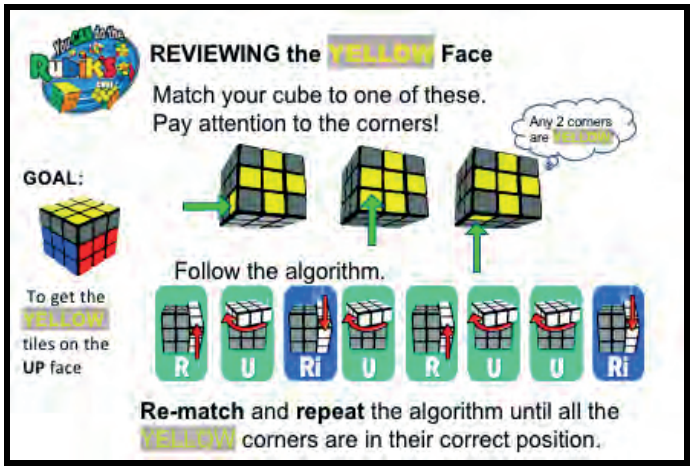
Grade	Common Core	NCTM
K-2	CCSS.MATH.CONTENT.K.G.B.4 Analyze and compare two- and three-dimensional shapes, in different sizes and orientations, using informal language to describe their similarities, differences, parts (e.g., number of sides and vertices/"corners") and other attributes (e.g., having sides of equal length).	**Algebra** ● Recognize and describe patterns **Geometry** ● Use visualization, spatial reasoning and geometric modeling to solve problems
3-5	CCSS.MATH.CONTENT.5.G.B.3 Understand that attributes belonging to a category of two- dimensional figures also belong to all subcategories of that category.	**Algebra** ● Analyze change in various contexts **Geometry** ● Predict and describe the results of sliding, flipping, and turning two-dimensional shapes
6-8	CCSS.MATH.CONTENT.7.G.B.5 Use facts about supplementary, complementary, vertical, and adjacent angles in a multi-step problem to write and solve simple equations for an unknown angle in a figure. CCSS.MATH.CONTENT.8.G.A.1 Verify experimentally the properties of rotations, reflections, and translations.	**Algebra** ● Represent and analyze mathematical situations and structures using symbolic language **Geometry** ● Create and critique inductive and deductive arguments concerning geometric ideas and relationships

Each lesson in this series begins with a review of the previous lesson and ends with a review of the current lesson. The review of the current lesson is always followed by a math extension which may or may not apply to your grade level. The last slide in each lesson is a trivia question. Many of the slides are animated so what you see in this guide may not appear all at once in the presentation. Please modify your presentation to best meet the needs of your students.

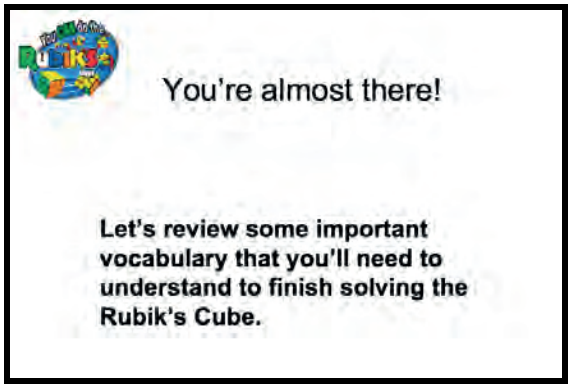
Review: Slides 2 - 4

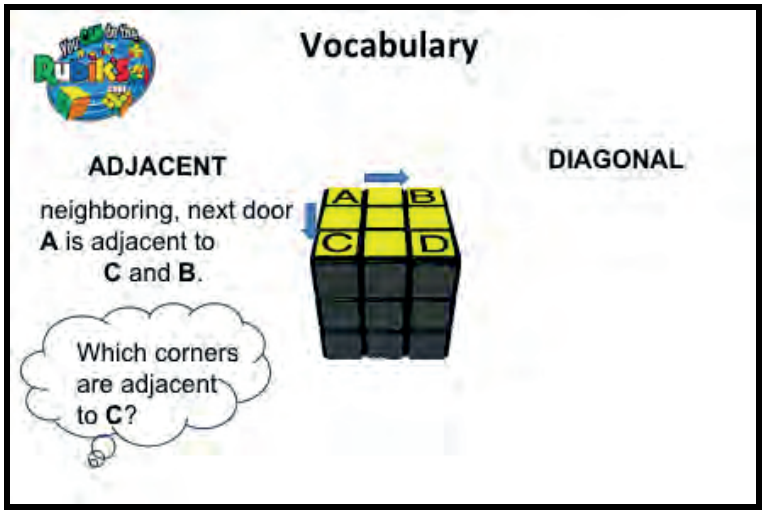




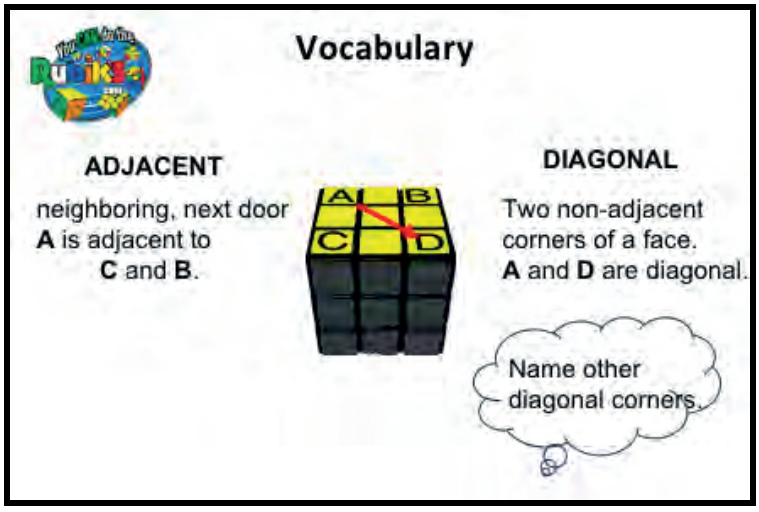


Vocabulary: Slides 6 - 8





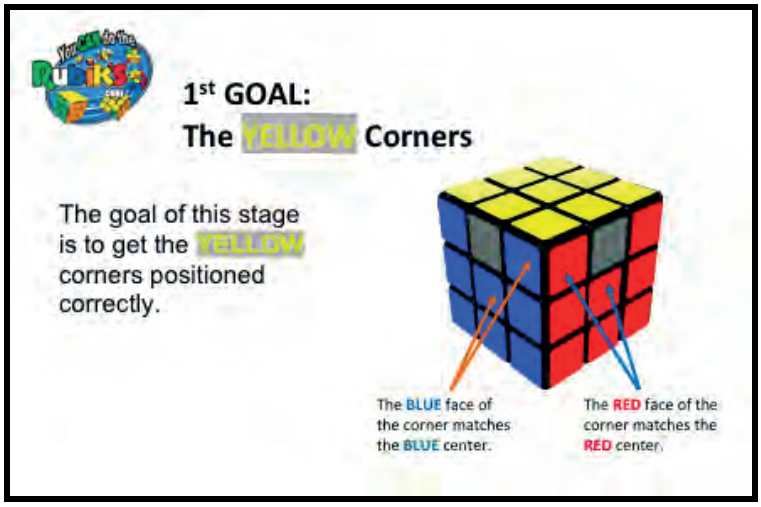
Adjacent corners or vertices are connected by the sides of the polygon. Vertex A is connected to vertex B and vertex C by the edges. Therefore, corner A is adjacent to corners B and C. Vertex A is not connected to vertex D so they are not adjacent corners. (Note that the terms vertex and corner are used interchangeably.) Vertex C is adjacent to A and D.



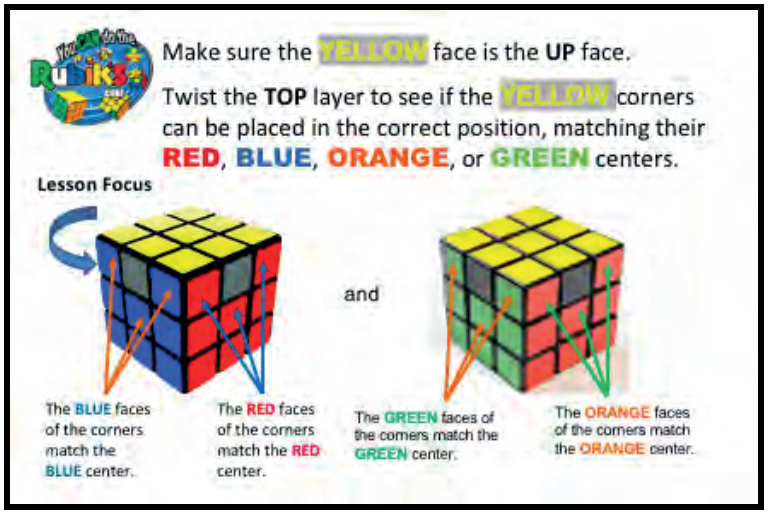
Diagonal vertices are not connected by the sides of the polygon. Vertex A is diagonal to vertex D. B and C are also diagonal vertices.

It is important that students begin to develop the understanding that diagonals are not "slanted" lines. A and D will always be diagonal vertices. If the cube in this slide is rotated 45^0, the line segment connecting them will be horizontal, not slanted.

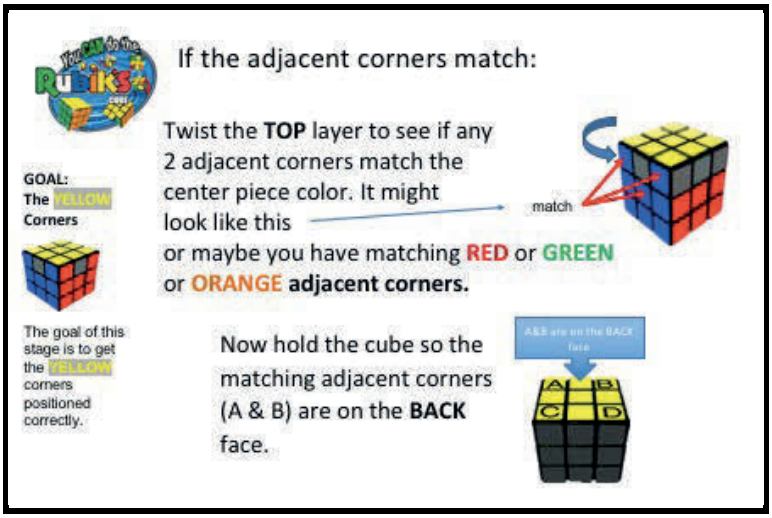
Lesson Content: Slides 8 - 23



This step differs from previous steps where the EDGES were aligned with the CENTER before the CORNERS. With the YELLOW face, the **CORNERS** are matched to their corresponding CENTERS **first**.



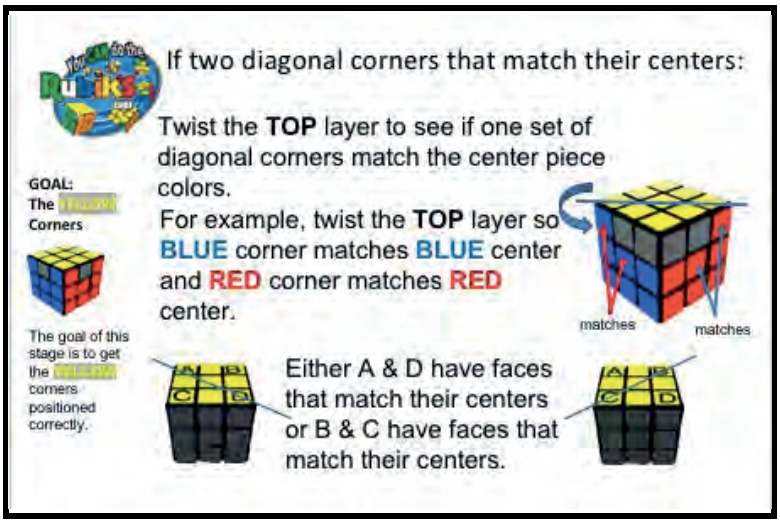
Some of the CORNERS can easily be aligned with their corresponding CENTERS by twisting the TOP layer.



First, check for adjacent corners that match their corresponding CENTERS. These adjacent corners will match the same CENTER tile. In the example, both CORNERS match the BLUE CENTER.

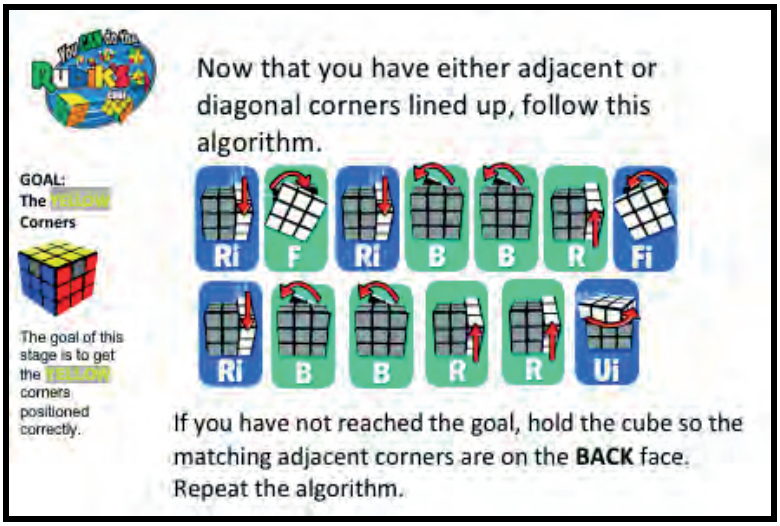
If there is a pair of matching adjacent CORNERS, hold the cube so they are away from you, on the BACK face.

Slides 11 - 13



Diagonal CORNERS that match their corresponding CENTERS will match different colored CENTERS. In this slide, the diagonal CORNERS match the BLUE and RED CENTERS.

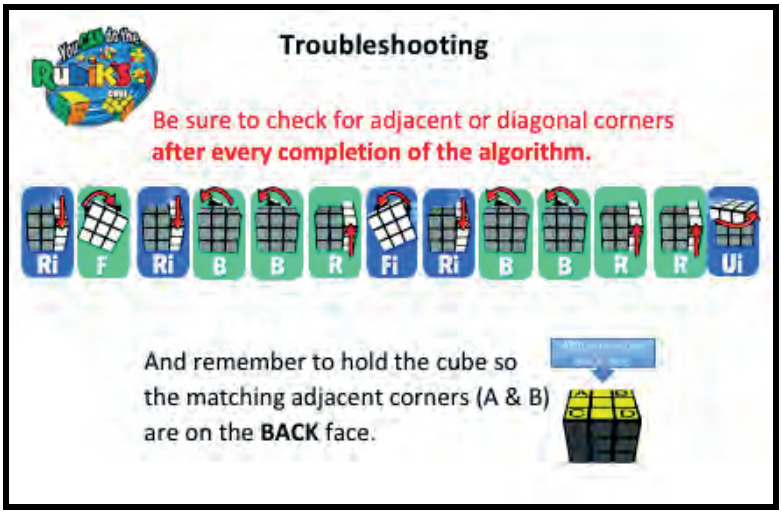
It does not matter which of the matching CORNERS is on the BACK face.



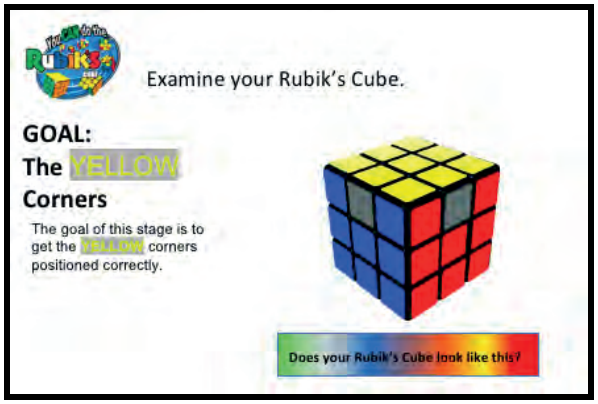
Whether CORNERS aligned or not, this algorithm may need to be repeated several times before the cube is solved.

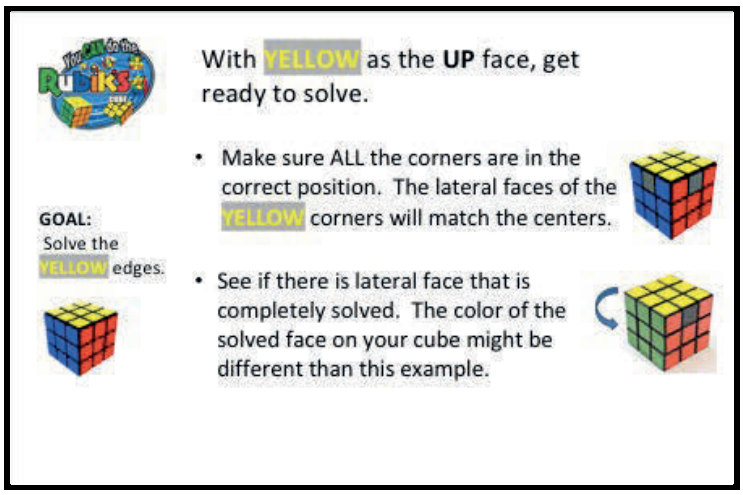
HINT: Keeping the cube on the table or desk may help students attend to the orientation of the cube which is an important concept as they solve.

This is especially important when attempting longer algorithms the first time. The excitement of nearly solving can be dashed when missteps scramble the cube.

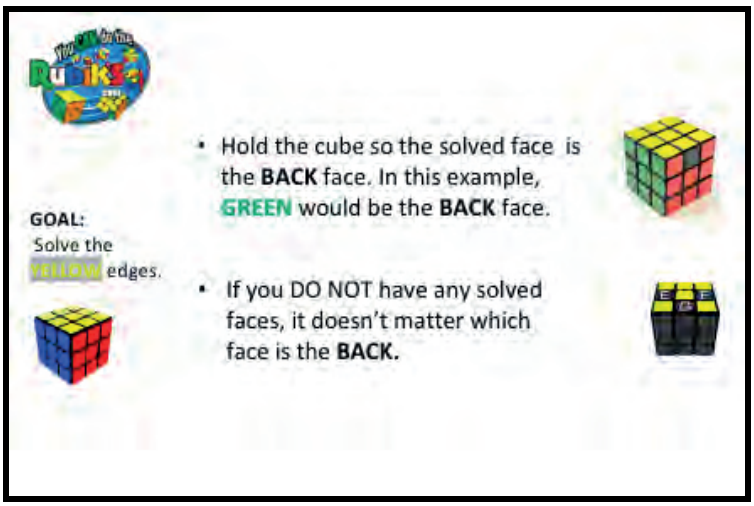


Slides 14 - 17





There may not be a lateral face that is completely solved.

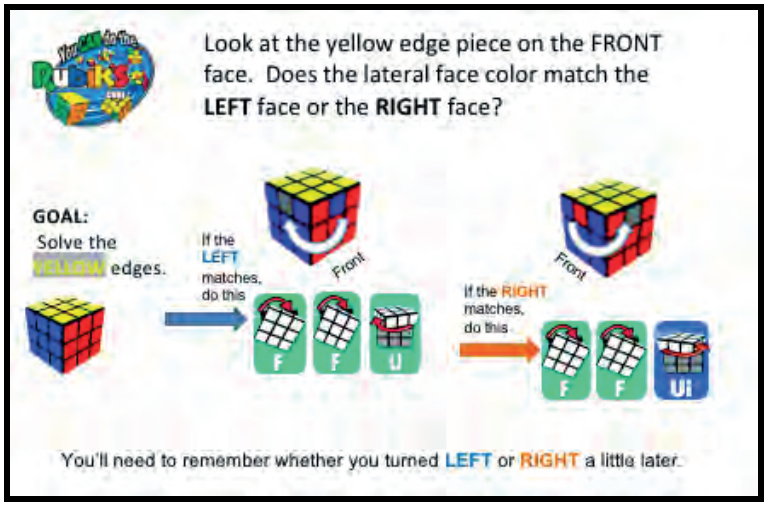


If there is a solved face, hold the Cube so the solved face is away from you, on the BACK face.

HINT: Keeping the cube on the table or desk may help students attend to the orientation of the cube which is an important concept as they solve.

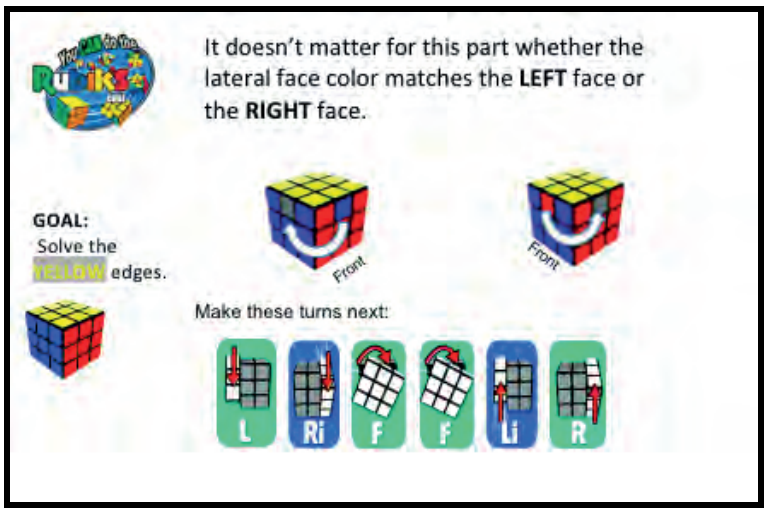
This is especially important when attempting longer algorithms the first time. The excitement of nearly solving can be dashed when missteps scramble the cube. It's worth mentioning again!

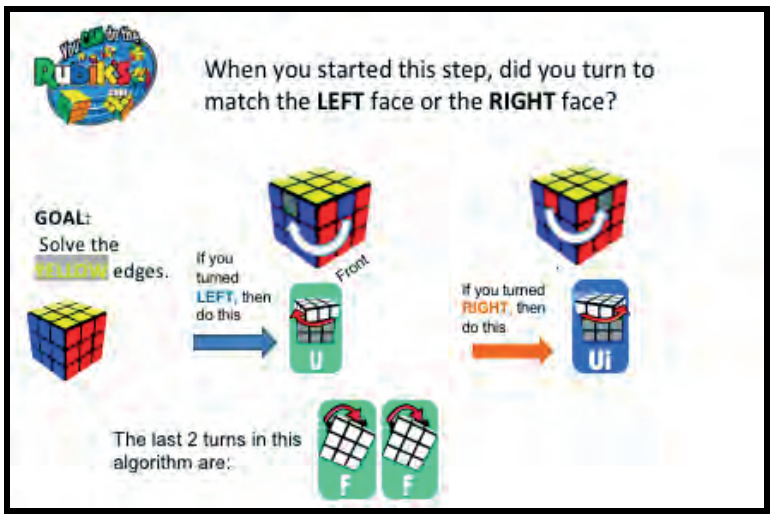
Slides 18 - 20



This can be a stumbling point for some solvers. If you turn the wrong way, you get stuck in an endless loop of repeating this step. And that's really frustrating!

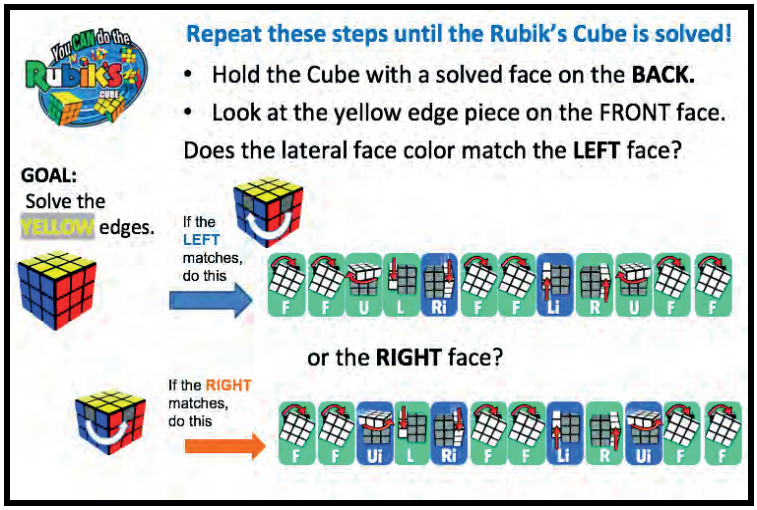
HINT: Match the arrows! If the EDGE tile matches the LEFT face, the third turn (slide 18) and tenth turn (slide 20) will be an UP turn to the LEFT. If the EDGE tile matches the RIGHT face, the third turn (slide 18) and tenth turn (slide 20) will be an UP turn to the RIGHT.





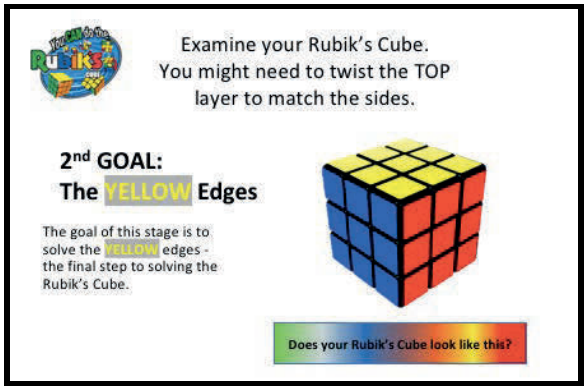
The last 2 turns are the same whether the cube was turned to the LEFT or the RIGHT earlier.

Slides 21 - 23

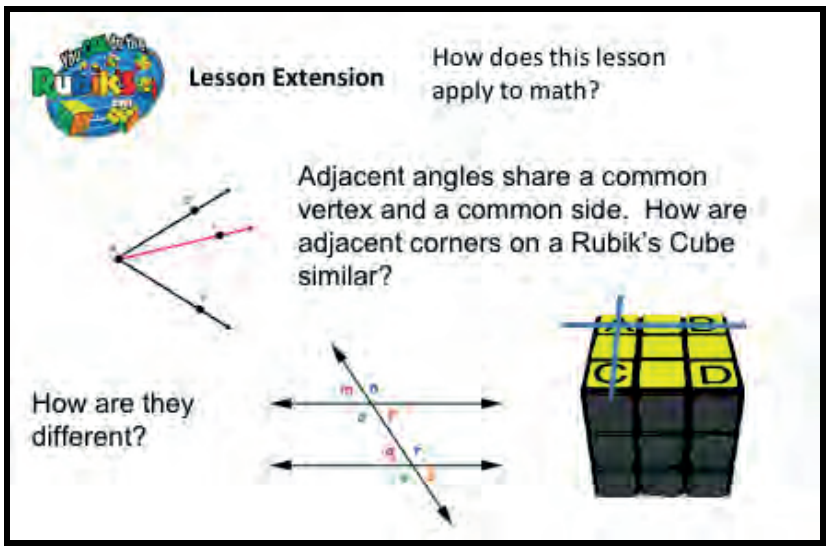


After completing the algorithm, stop to check which side the EDGE tile matches.

This algorithm matches all the tiles in the top row of the lateral faces. Sometimes the top row tiles will all be the same color but not match the CENTER tile. A twist (or 2) of the TOP layer should make everything right.

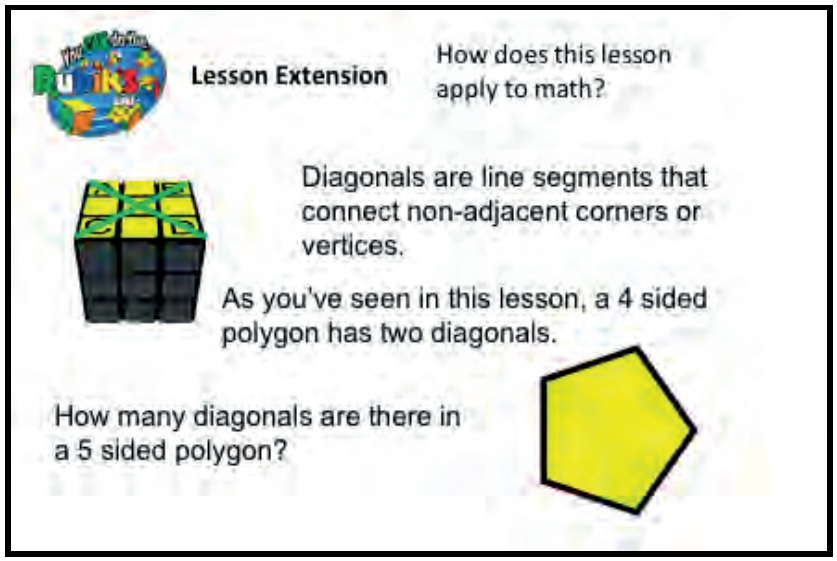


Math Connections: Slides 24 - 25



Similarities: One could make the case that the corners adjacent to A are on the sides of angle A. A is the vertex formed by the lines connecting the adjacent corners; point A is the vertex of the adjacent angles. The intersecting segments that connect the adjacent corners form adjacent (and vertical) angles.

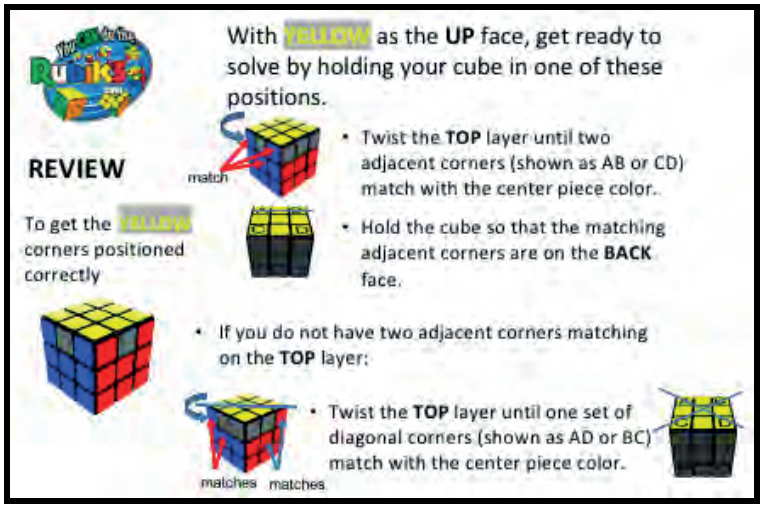
Difference: Adjacent angles share a common vertex and a common side. Angle DAJ and angle JAT are adjacent because the share vertex A and have ray AJ as a common side. Pairs of adjacent corners on a cube have a common vertex but do not share a common side.

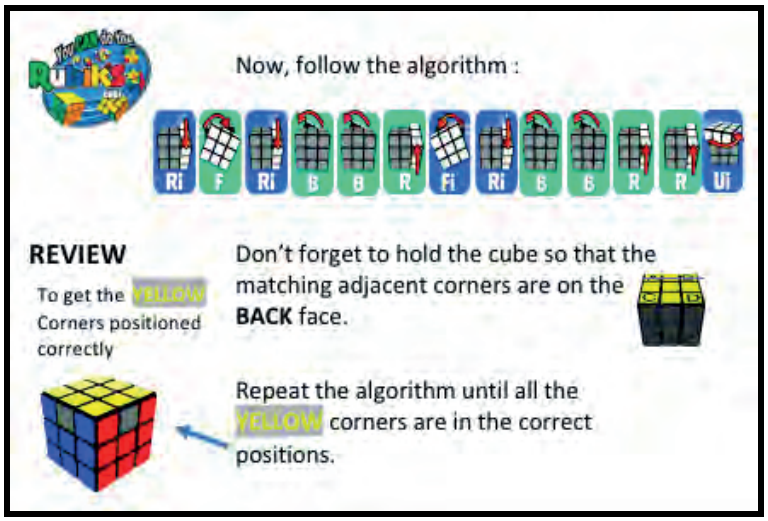


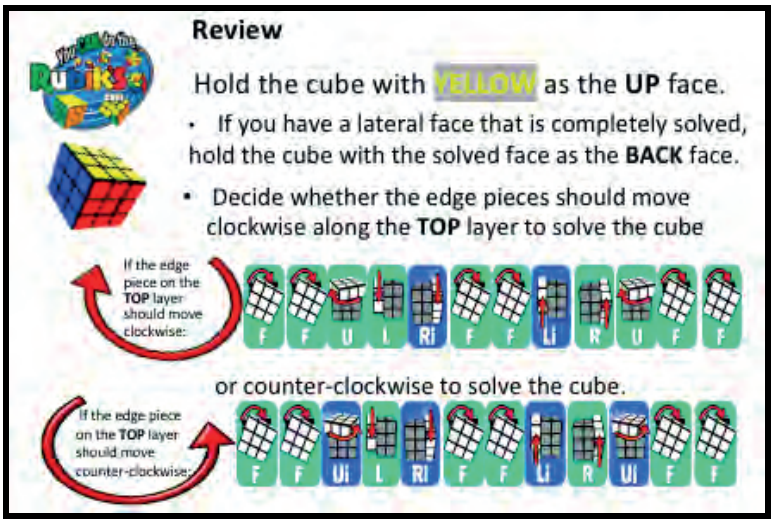
As stated earlier in this lesson, it is important that students begin to develop the understanding that diagonals are not "slanted" lines. One might use this opportunity to explore diagonals in other polygons. Triangles have no diagonals. In polygons with more than 4 sides, there is more than one diagonal from any given vertex. Older students may find the pattern in the total number of diagonals in a polygon and generalize that pattern algebraically.

Review: Slides 26 - 28

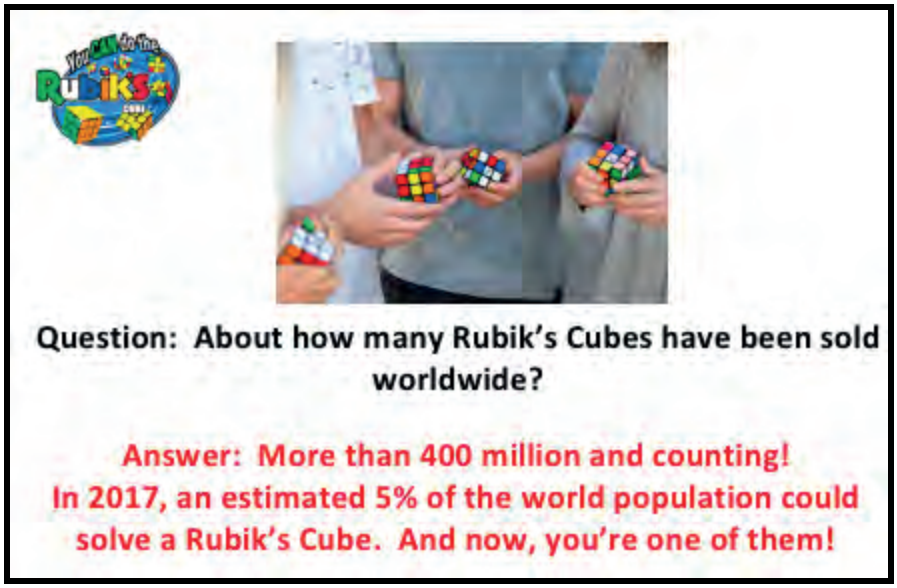
These slides could be printed as a reference for students, perhaps in a learning center.







TRIVIA: Slide 29



The reported percentage of the world population that can solve a Rubik's Cube in 2017 varied from 3% to 6%. Some students may be challenged to figure out how many new solvers it would take to increase the percentage 1%.

Check List For Solving The Rubik's Cube

Updated Stages 2&3

Check each box as you move forward!

Stage 1

- [ ] I found the WHITE Rubik's Cube logo center piece and it's on the bottom of my Cube.

Stage 2

- [ ] I made a daisy on the YELLOW face by putting the WHITE edge pieces next to the YELLOW center piece.
- [ ] One at a time, I matched each edge piece to its center and made 2 turns of the FRONT face.
- [ ] I flipped my Cube over.
- [ ] I completed the WHITE Cross.

Stage 3

- [ ] I held my Cube so the WHITE face is UP.
- [ ] I found a three color corner piece with a WHITE tile on it
- [ ] I moved the corner piece directly below the place it belongs on the top layer.
- [ ] I followed the sequence to move the corner piece to the top layer of the Cube.
- [ ] I put all 4 WHITE corners in their correct locations.

Stage 4

- [ ] I turned my Cube upside down so the WHITE face is on the bottom.
- [ ] I made a vertical row of one color.
- [ ] I determined if the edge piece needs to move to the left or right.
- [ ] I followed the sequence to move the edge piece from the top layer of the Cube into the middle layer.
- [ ] I have all the edge pieces in their correct locations in the middle layer.

Stage 5

- [ ] I matched the YELLOW edge pattern on my Cube to one of the patterns.
- [ ] I completed the sequence until I have a YELLOW Cross on the UP face of my Cube.
- [ ] I matched the YELLOW corners pattern on my Cube to one of the patterns.
- [ ] I completed the sequence until I have all YELLOW tiles on top of my Cube.

Stage 6

- [ ] I matched two corners to their center color so they are in their correct locations.
- [ ] I held my Cube with the correct corners on the BACK face of the Cube.
- [ ] I followed the sequence to position all 4 corners into their correct positions.
- [ ] I counted how many edge pieces are in their correct locations.
- [ ] I identified what direction the edge pieces need to be moved.
- [ ] I followed the sequence to move the edge pieces into their correct locations.
- [ ] I SOLVED THE RUBIK'S CUBE!

Check us out online at

www.YouCanDoTheCube.com

- Borrow from our Cube Lending Program
- Purchase a Rubik's Cube Education Kit
- Make a Rubik's Cube Mosaic
- Host a Team Competition

Thank you to Tyson Mao, Jasmine Lee, and Dan Harris for your inspiration to this guide. Thank you to all of the Daisy Method contributors.